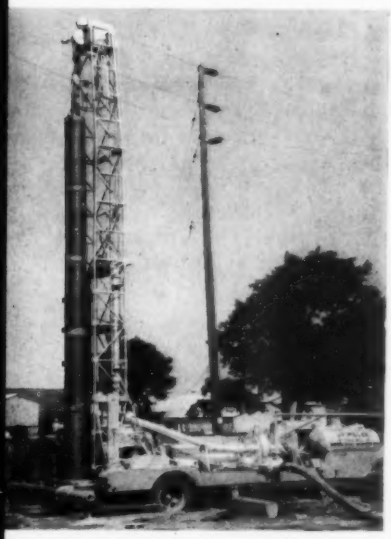
MARCH 1960

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 52 • NO. 3



Boring but not dull—rotary rig spins well at Paxton, Ill.

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Task Group Report

WEST VIRGINIA RATES AND FINANCING
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SOIL CONDUCTIVITY AND UNDERGROUND CORROSION
Scott

AWWA CONSTITUTION AND BYLAWS REVISION

1960 AWWA CONFERENCE
Bal Harbour, May 15–20

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Journal

AMERICAN WATER WORKS ASSOCIATION

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March 1960
Vol. 52 • No. 3

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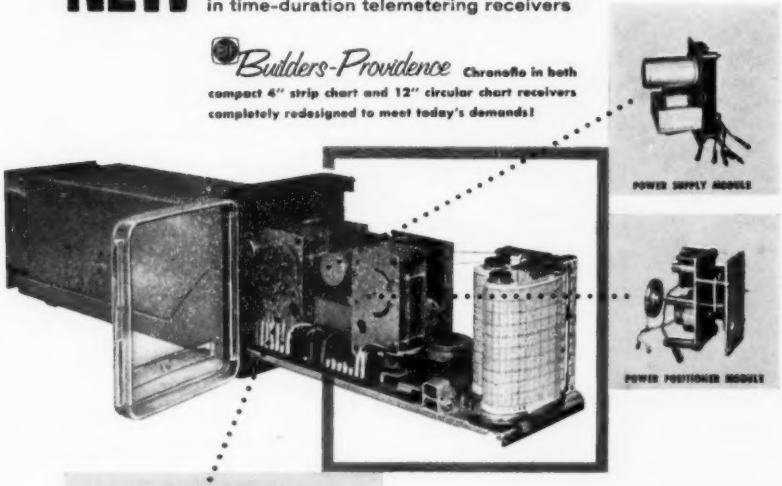

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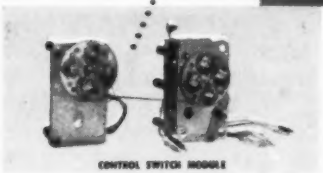

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AWWA ANNUAL CONFERENCE

Bal Harbour, Fla. May 15–20, 1960

See page 60 P&R for preliminary program.

Coming Meetings

AWWA SECTIONS

Spring 1960

Mar. 16–18—Illinois Section, at Pick-Congress Hotel, Chicago. Secretary, D. W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Mar. 17—New England Section, at Statler Hotel, Boston, Mass. Secretary, R. M. Soule, Assoc. San. Engr., State Dept. of Public Health, 511 State House, Boston, Mass.

Mar. 20–23—Southeastern Section, at De Soto Hotel, Savannah, Ga. Secretary, N. M. de Jarnette, Engr., Water Quality Div., State Dept. of Public Health, 309 State Office Bldg., Atlanta, Ga.

Mar. 24–25—West Virginia Section, at Hotel Pritchard (tentative), Huntington. Secretary, H. W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

Apr. 5–7—New York Section, at New York Sheraton Inn, Binghamton. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

Apr. 20–22—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, J. J. Rossbach Jr., Civ. Engr., Metropolitan Utilities Dist., 3906 N. 48th St., Omaha.

Apr. 20–22—Kansas Section, at Broadview Hotel, Emporia. Secretary, H. W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 22—California Section, at Mark Thomas Inn, Monterey. Secretary, R. E. Dodson Jr., Supt. of Water, Dept. of Utilities, Balboa Park, San Diego.

Apr. 24–27—Canadian Section, at Statler Hotel, Buffalo, N.Y. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Apr. 28–30—Arizona Section, at Pioneer Hotel, Tucson. Secretary, A. D. Cox Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

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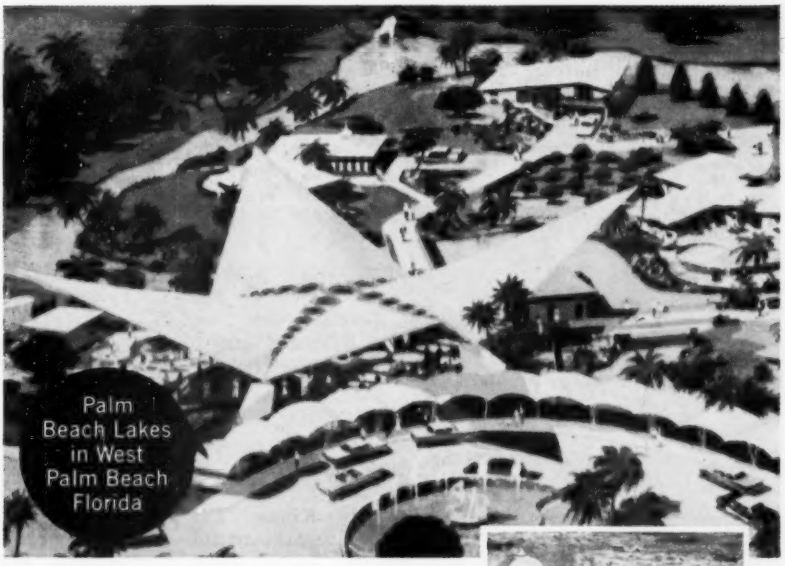

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Coming Meetings

(Continued from page 6)

Apr. 28–30—Montana Section, at Northern Hotel, Billings. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

May 4–6—Pacific Northwest Section, at Benson Hotel, Portland, Ore. Secretary, F. D. Jones, W. 2108 Maxwell Ave., Spokane 11, Wash.

Jun. 14–17—Pennsylvania Section, at Hilton Hotel, Pittsburgh. Secretary, L. S. Morgan, 413 First National Bank Bldg., Greensburg.

Fall 1960

Sep. 12–14—Kentucky-Tennessee Sec., Knoxville, Tenn.

Sep. 14–16—Virginia Sec., Virginia Beach.

Sep. 14–16—New York Sec., Whiteface.

Sep. 21–23—Michigan Sec., Traverse City.

Sep. 21–23—North Central Sec., Sioux Falls, S.D.

Sep. 25–27—Missouri Sec., Jefferson City.

Sep. 28–30—Wisconsin Sec., Madison.

Oct. 9–12—Alabama-Mississippi Sec., Birmingham, Ala.

Oct. 16–19—Southwest Sec., Galveston, Tex.

Oct. 19–21—Iowa Sec., Des Moines.

Oct. 19–21—Chesapeake Sec., Washington, D.C.

Oct. 20–22—New Jersey Sec., Atlantic City.

Oct. 23–26—Rocky Mountain Sec., Colorado Springs, Colo.

Oct. 24–27—California Sec., Long Beach.

Oct. 26–28—Ohio Sec., Columbus.

Nov. 9–11—North Carolina Sec., Winston-Salem.

Nov. 13–16—Florida Sec., Fort Lauderdale.

OTHER ORGANIZATIONS

Mar. 14–18—National Assn. of Corrosion Engineers Annual Convention, Memorial Auditorium, Dallas, Tex.

Mar. 16–18—23rd Short Course for Superintendents and Operators of Water and Sewerage Systems, Louisiana State University, Baton Rouge, La. Write: Fred H. Fenn, Dean, College of Engineering, at the university.

Apr. 3–8—6th Nuclear Congress, Coliseum, New York, N.Y., sponsored by EJC and other engineering and scientific societies, including AWWA.

Apr. 6—Conference on Water Softening and Stabilization of Softened Water, cosponsored by Missouri Section, AWWA, and the University of Missouri, at Columbia, Mo. Write: Warren Kramer, Div. of Health, Jefferson City, Mo., or Amos J. Snider, Director, Div. of Continuing Education, Univ. of Missouri, Columbia, Mo.

Apr. 27–29—Conference on Algae and Metropolitan Wastes, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: A. F. Bartsch, Asst. Chief for Special Technical Services, Water Supply & Water Pollution Research, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

May 9–13—2nd Southwestern Metal Exposition & Congress, American Society for Metals, with other technical groups, State Fair Park & Sheraton Hotel, Dallas, Tex. Write: Allan Ray Putnam, Managing Director, Metals Park, Novelty, Ohio.

Jun. 1–3—5th Appalachian Underground Corrosion Short Course, West Virginia University, Morgantown, W.Va. Write: John H. Alm, Rm. 605, 2 Gateway Center, Pittsburgh 22, Pa.

Jun. 8–11—National Society of Professional Engineers, Statler Hotel, Boston, Mass.

Jun. 20–24—Summer general meeting, AIEE, Atlantic City, N.J.

Jun. 26–Jul. 1—ASTM, Chalfonte-Haddon Hall, Atlantic City, N.J.

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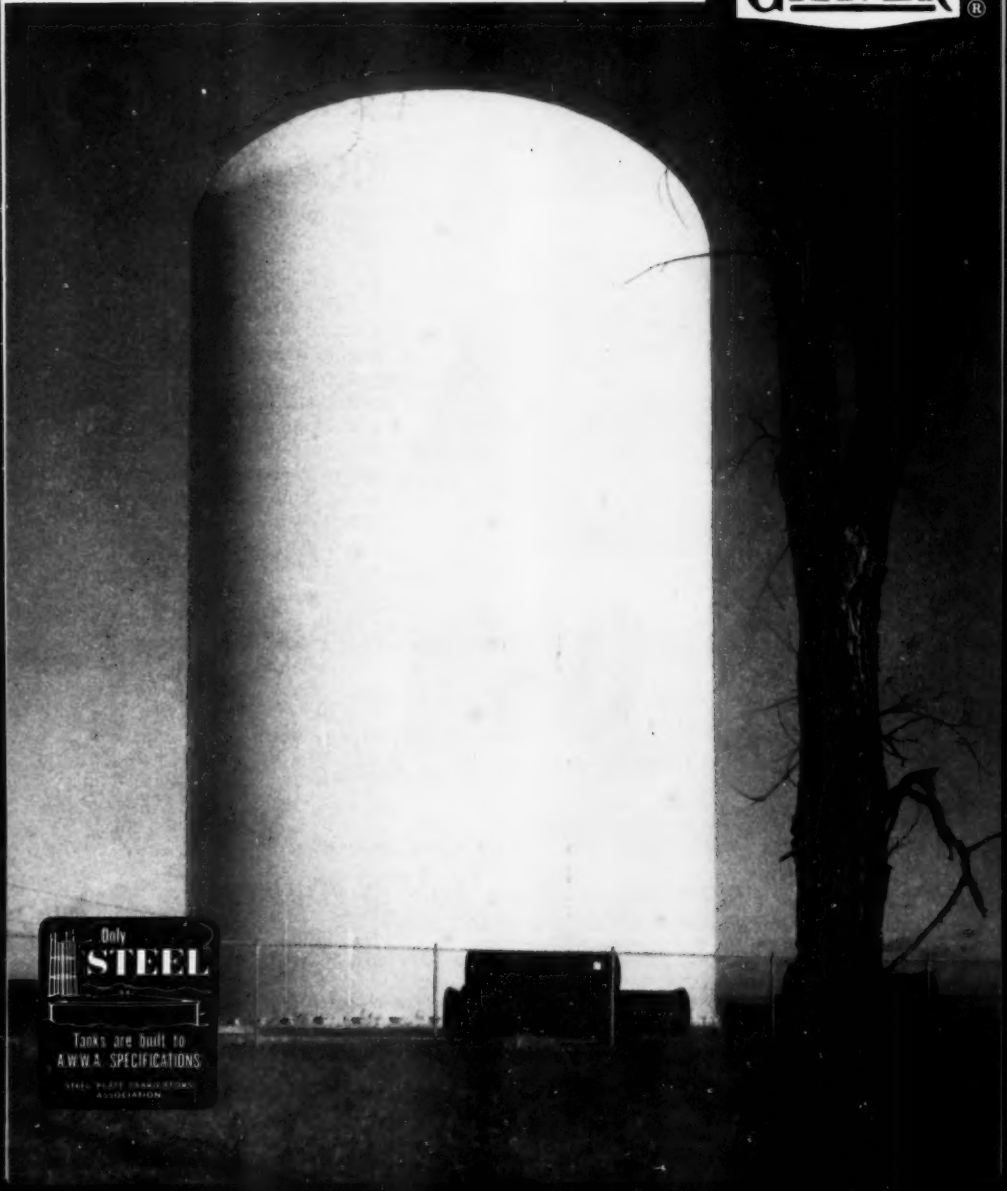

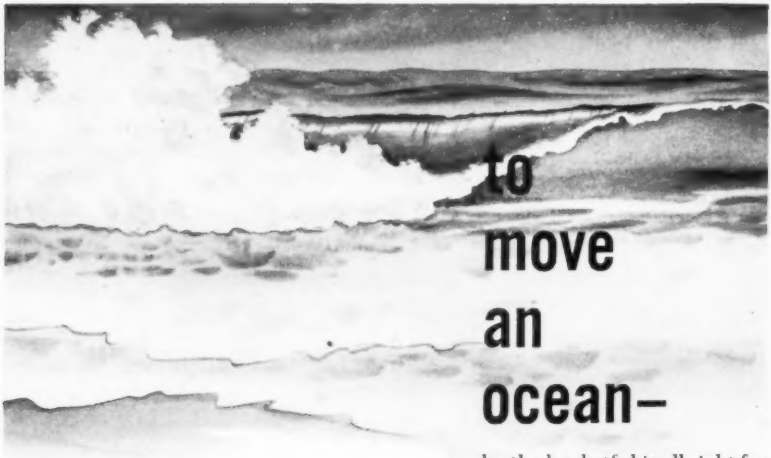

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WRITE FOR ILLUSTRATED BULLETIN NO. B-148

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Offices: New York; Atlanta; St. Louis; Phoenix; San Francisco; Chicago; Fresno; Los Angeles; Plainview and Lubbock, Texas; Albuquerque. Distributors in Principal Cities. Consult your telephone directory.

New Nalco Coagulant Makes Bigger, Heavier Floc . . . Faster

Nalcolyte 110 boosts Capacity of existing Treatment facilities

Nalcolyte 110 is a new, non-ionic organic coagulant of high molecular weight—over 1,000,000. It is used with conventional coagulants such as sodium aluminate and alum to increase size, density and uniformity of the floc.

May be used in public water supplies

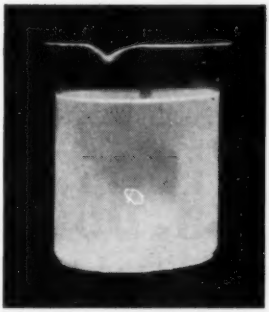
Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 speeds formation of tough, high-density floc as shown in the photos at right. In this case a single ppm of Nalcolyte 110 replaced 30 ppm of a conventional coagulant . . . *and produced a clearer water.*

Greater Capacity; Better Water

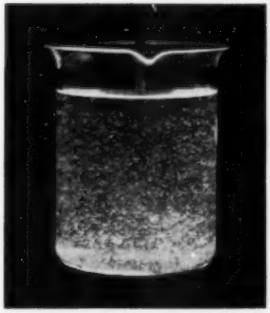
Small dosages of Nalcolyte 110 produce a fast-settling floc that permits increased throughput without danger of carryover and plugging of filters. If your problem is to produce clearer water, and more of it, Nalcolyte 110 is the newest, most feasible answer.

Full Data Available

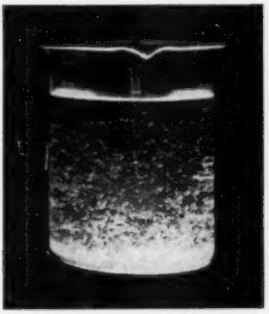
Write or call for details on this new, potent coagulant today . . . for better flocculation . . . greater capacity . . . lower costs.



Untreated control sample of a turbid raw water.



Same water with 50 ppm alum added, photographed 7 seconds after ceasing agitation.



Same water with 20 ppm alum and 1 ppm Nalcolyte 110 added. Photo 7 seconds after stopping agitation shows rapid settling rate of larger, denser floc.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY

6315 West 66th Place Chicago 38, Illinois

In Canada: Alchem Limited, Burlington, Ontario

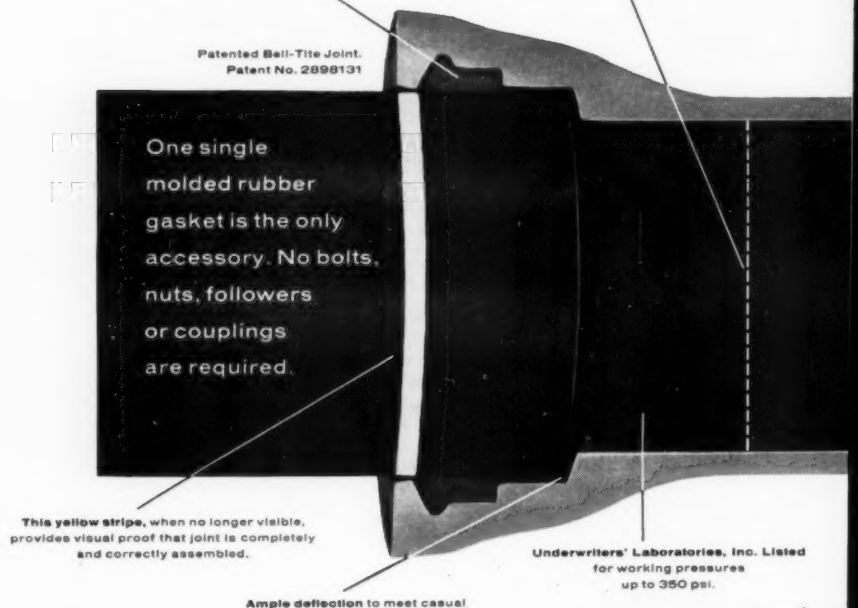
Nalco®

CHEMICALS

. . . Serving industry through Practical Applied Science

CLOW

Quick, Bottle-Tight Seal


Large, thick section gasket of long-life high durometer rubber forms pressure-tight seal.
Bell-Tite Joint Pipe available in diameters from 3" thru 24" in 18 foot lengths.
Patented Bell-Tite Joint. Patent No. 2898131
One single molded rubber gasket is the only accessory. No bolts, nuts, followers or couplings are required.
This yellow stripe, when no longer visible, provides visual proof that joint is completely and correctly assembled.
Underwriters' Laboratories, Inc. Listed for working pressures up to 350 psi.
Ample deflection to meet casual curves or grades is provided by space in socket of the bell.

CLOW CAST IRON PIPE

Cast Iron Pipe Plants at

SENSENVILLE, ILLINOIS • BIRMINGHAM, ALABAMA • COSHOCTON, OHIO

CAST IRON PIPE

You can install

CLOW BELL-TITE® JOINT PIPE

as fast as you can dig a shallow trench

Pictures show CLOW 20" Bell-Tite Joint Cast Iron Pipe being installed to provide water for a midwestern industrial development. CLOW Bell-Tite Joint Cast Iron Pipe was selected because of its proved long life and the ease and speed of installation. Hulett Corporation, contractors.

LOWER pipe into trench

SWING into open bell

SEAL for pressure-tight joint

JAMES B. CLOW & SONS, INC.
201-299 North Talman Avenue, Chicago 80, Illinois

Subsidiaries:
Eddy Valve Company, Waterford, N.Y.
Iowa Valve Company, Oskaloosa, Iowa

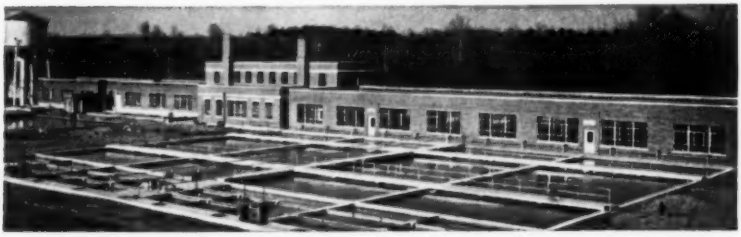
Roberts Filter Manufacturing Co.

DARBY, PENNSYLVANIA

WATER PURIFICATION EQUIPMENT

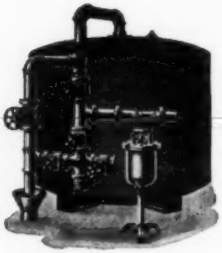
STANDARD OF QUALITY FOR MORE THAN 60 YEARS

WATER FILTRATION PLANTS and EQUIPMENT
GRAVITY FILTERS and EQUIPMENT—PRESSURE FILTERS (Vertical & Horizontal)—WATER SOFTENING EQUIPMENT
SWIMMING POOL EQUIPMENT



This 8 million gallon a day water treatment plant is typical of the many hundreds of Roberts-equipped installations throughout the United States, Canada and Latin America. We welcome the opportunity to cooperate with engineers on all types of water filtration equipment projects.

- **Dependability**
- **Experience**
- **Engineering Cooperation and Service**



Roberts Style L
Vertical Pressure Filter

SWIMMING POOL EQUIPMENT

This modern pool at Levittown, Pa., built by Levitt and Sons, Inc., is representative of the thousands of Roberts-equipped swimming pools. We produce a complete line of swimming pool recirculating plants and filtration equipment, backed by more than 60 years experience in the field of water purification.

ASK THE MAN WHO USES HTH

what's best for CHLORINATING new mains

He knows dependability, convenience and economy are the three reasons why HTH Tablets are the modern, preferred way to chlorinate new mains. Containing 70% available chlorine, they assure quick elimination of bacteria, fungi and algae.

HTH Tablets are easy to use—you simply attach them to the inside top of every pipe. When the pipe is filled with water, the chlorine is carried to all interior surfaces of the pipe. Because the tablets are slow dissolving, they provide a long-lasting chlorine residual throughout the pipeline, assuring complete chlorination.

For further information on this proved chlorination method, write today.

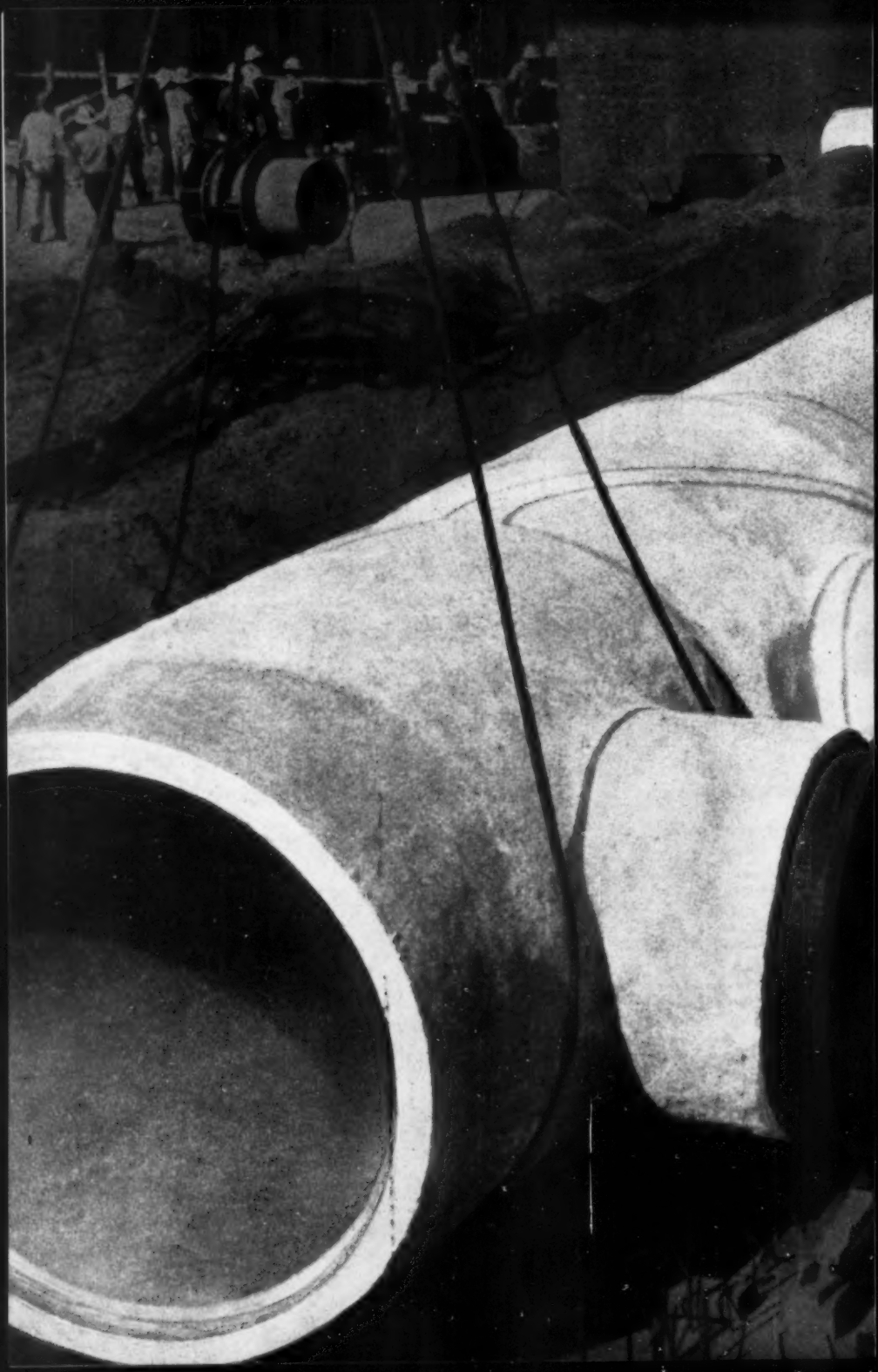
HTH TABLETS are packed in 100-lb. steel drums and in cases of twelve 3¼-lb. cans.

For your protection, every genuine HTH TABLET is stamped HTH.

HTH® is a trademark

OLIN MATHIESON
CHEMICAL CORPORATION
CHEMICALS DIVISION • BALTIMORE 3, MD.

6460



Concrete Pressure Pipe...

FOR RELIABLE PLANT PIPING

In congested plant areas housing vital and costly equipment, major piping materials must, above all, be reliable. Conclusive evidence of concrete pressure pipe's reliability lies in its unexcelled record for durability, trouble-free service and exceptional safety.

Plant piping must also be adaptable. The tailor-made characteristics inherent in concrete pressure pipe design make it an ideal material to meet the complexities of accurate entry into structures, and of precise juncture with fittings within the limited confines of plant buildings.

Dependable, maintenance-free, and with sustained high carrying capacity, concrete pressure pipe assures reliable plant piping, whether for water or sewage treatment plants, for industrial supply lines, or for cooling or process water systems.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

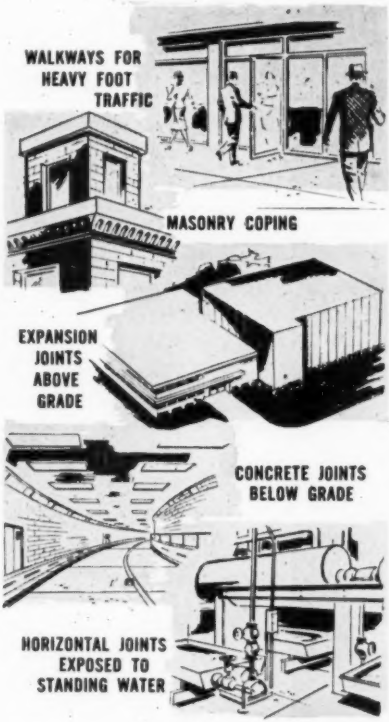
AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

228 North LaSalle Street, Chicago 1, Illinois

For POSITIVE Sealing of Horizontal and Vertical Joints

Specify and Use

SERVICISED VERTISEAL®


WALKWAYS FOR HEAVY FOOT TRAFFIC
MASONRY COPING
EXPANSION JOINTS ABOVE GRADE
CONCRETE JOINTS BELOW GRADE
HORIZONTAL JOINTS EXPOSED TO STANDING WATER

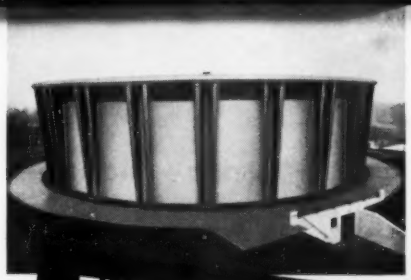
- Maintains positive bond from below 0°F to 150°F
- No cold flow after cure
- Highly resilient—will not work harden
- Waterproof
- Non-Shrinking
- Weatherproof
- 3 Types—Pouring, Troweling or Gun Trade

Servicised Vertiseal is a cold applied, general purpose self-curing joint sealer for positive sealing of horizontal or vertical joints. It is a two-component material manufactured with Thiokol * Polysulfide Liquid Polymers, and is available in widely used standard colors—Gray, Black, and Tan. In addition to its other qualities, Vertiseal is resistant to petroleum derivatives, most common acids, fats, and alkalis. Write for Technical Bulletin and Catalog.

* Thiokol is a registered name of the Thiokol Chemical Corporation

SERVICISED PRODUCTS CORPORATION

6051 WEST 65th STREET · CHICAGO 38, ILLINOIS



A striking example of fine appearance and exacting craftsmanship is this PDM Steel Reservoir built for the Municipal Authority of the Borough of West View, Pa., in a high-value residential district. An entire hilltop was removed to make room for the 5,000,000 gallon structure, special architectural detailing employed for visual appeal, and a two-tone blue color scheme applied to complete a most unusual and applauded neighborhood feature. • Do you have a particular water storage problem? Let us discuss it with you!

THE CONSTRUCTION QUALITY TELLS YOU it's Pittsburgh-Des Moines

5,000,000 Gallon Reservoir, 150 ft diameter by 40 ft high, built for the Municipal Authority of the Borough of West View, Pa. in Ross Twp., Allegheny County. Structure designed by William Murdoch, Consulting Engineer, Pittsburgh, Pa.

PDM
STEEL RESERVOIRS

Pittsburgh-Des Moines Steel Company

Plants at PITTSBURGH, WARREN, BRISTOL, PA. • BALTIMORE • BIRMINGHAM • DES MOINES
PROVO, UTAH • CASPER, WYO. • SANTA CLARA, FRESNO, STOCKTON, CALIF.

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PITTSBURGH (25)	3424 Neville Island	DES MOINES (8)	925 Tuttle Street
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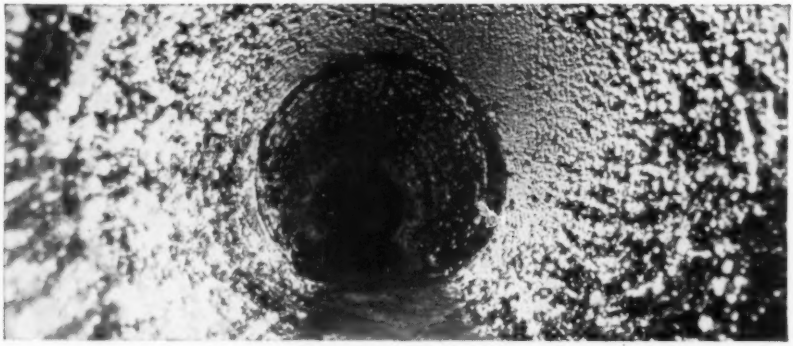
NEWARK (2)	744 Broad St.	SEATTLE (1)	Suite 332, 500 Wall St.
CHICAGO (3)	628 First National Bank Bldg.	SANTA CLARA, CALIF.	631 Alviso Road
ATLANTA (5)	361 E. Paces Ferry Rd., N.E.	EL MONTE, CALIF.	P. O. Box 2012
JACKSONVILLE (7)	4066 Ferrara Road	PROVO, UTAH	P. O. Box 310

Use CALGON® TG during the "critical" period—because

TUBERCULATION ACTS FAST



The picture (taken 8 months after main cleaning) shows what happens to water mains during the "critical" period—the first few months after cleaning. The way to prevent this is to make sure that the freshly scored metal is protected *immediately*—and that means Calgon Composition TG, the treatment that forms a protective film *fast*.

The moment bare metal is exposed by cleaning, corrosion starts. The best way to make sure that corrosion of clean metal and in old pits does not get a head start is to get a protective film on the metal immediately. Put Calgon Composition TG right behind the scraper, so that this fast film-forming chemical can beat corrosion to the punch. It will also help disperse the removed corrosion products, making it easier to flush them from the main.

Calgon Composition TG has other benefits, too, when used in continuous treatment. (1) It makes "red water" complaints a thing of the past. (2) It is especially helpful in areas of low flow, and when temperatures go up. (3) Its greater efficiency keeps chemical costs down.

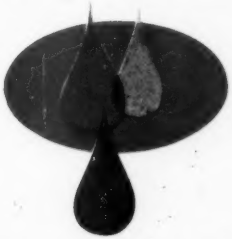
A letter or phone call will bring you more information on how Calgon can help. Or, a Calgon engineer, experienced in controlling water problems of all kinds, will be glad to make detailed recommendations on your specific problem.

CALGON COMPANY
HAGAN BUILDING, PITTSBURGH 30, PA.

DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.

ARE YOU SACRIFICING

POTENTIAL PUMPABILITY



Of course you are not willing to write off the substantial costs of a water well because of excessive drawdown! In many cases a decrease in production can not only be halted . . . it can often be reversed and returned to near the initial rate . . . by servicing or treating problem wells with advanced Halliburton Water Well Service Equipment and Techniques.

Your Halliburton Representative can show you how to improve your well's productivity by helping you select a proper service for a specific problem. Halliburton equipment and experienced personnel are available throughout the country – day or night – to provide you with services such as . . .

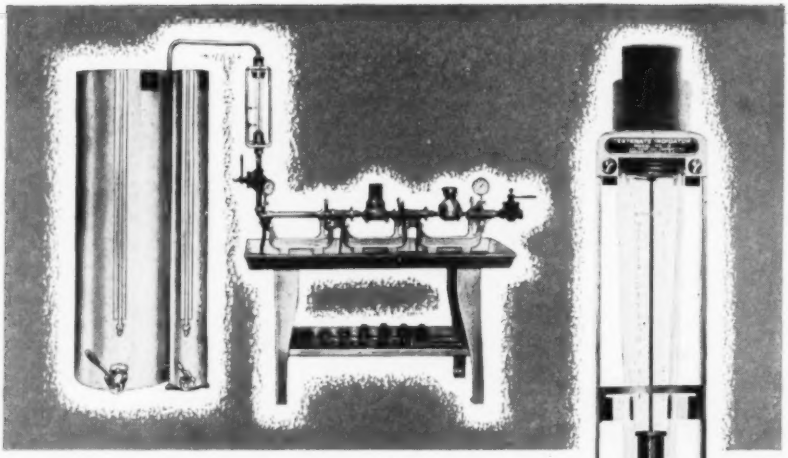
* CEMENTING
* FORMATION TESTING
* ACIDIZING
* FORMATION FRACTURING
* HYDRO-SONIC REDEVELOPMENT
* SPECIAL TOOLS

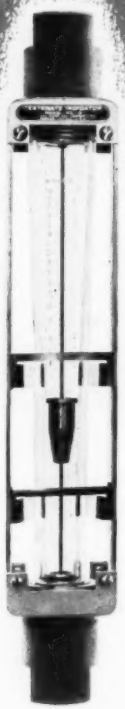
Contact your nearest Halliburton Representative for full details.

HALLIBURTON

WATER WELL SERVICES

HALLIBURTON OIL WELL CEMENTING COMPANY • DUNCAN, OKLAHOMA





Check

RATE OF FLOW AT A GLANCE

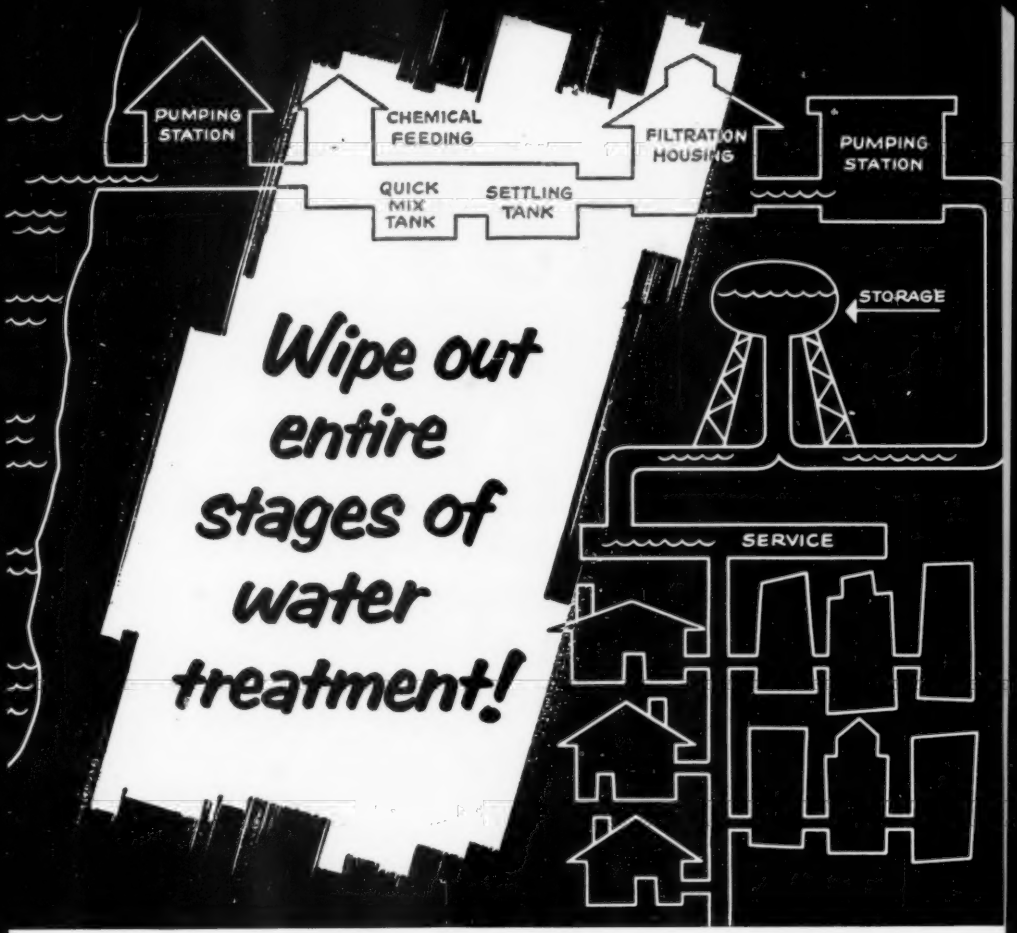
Complete and accurate water meter testing requires definite knowledge of rates of flow. The Ford Testerate Indicator provides quick, precise readings in gallons per minute and is a useful and valuable accessory in any modern meter shop. Accuracy is within 2% down to 1 GPM, and the operator can make corrected readings with rates of flow as small as ¼ GPM.

Easily connected to any meter testing outfit. Write for complete information.

FOR BETTER WATER SERVICES

FORD

THE FORD METER BOX COMPANY, INC. Wabash, Indiana



A complete Celite diatomite filtration system can eliminate the costs of conventional pre-treatment facilities

Now you can do something about skyrocketing per capita water consumption costs—as are dozens of municipalities every year. And get clearer, sparkling-bright water in the bargain!

Install one of today's small compact diatomite filtration plants, using Celite* filter aids. In many cases, raw water can be filtered directly, eliminating several of the costly conventional pretreatment stages—flocculation, quick-mixing tanks, and settling tanks, for example.

Result†: Filtration plants requiring only ¼ the space of sand plants of equal capacity. Capital costs cut almost in half—savings of up to 45%.

Here's why. Celite diatomite filters better than any other medium. Every cubic inch of the skeletal diatomite particles contains millions of microscopic filter pores. These are so minute they remove all suspended solids, including amoebae and algae, without flocculation.

Mined by Johns-Manville from the world's purest commercially available diatomite deposit, Celite is carefully processed for uniformity. You have a wide choice of grades for best balance of clarity and flow rate. For further information, call your nearby J-M Celite engineer. Write direct for free technical reprints and illustrated brochure. Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

* Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

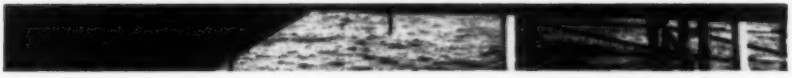
† See *Comparison Studies of Diatomite and Sand Filtration* by G. R. Bell, Journal American Water Works Association, September, 1956, or write for free reprint.

JOHNS-MANVILLE JM

FIRST

first off-shore sulphur production in the

world will move through Reilly-coated lines



Seven miles off Grand Isle, Louisiana, sulphur will be raised by the Freeport Sulphur Company from a mine 2,000 feet below the ocean floor. Reilly Hot Coal Tar Enamels—Hot Service Enamel with HS X-1 Primer—applied by Pipe Line Service Corporation—will protect delivery lines to shore installations against salt water and other corrosive elements. Inquire at any Reilly Sales Office.

REILLY TAR & CHEMICAL CORP

1615 MERCHANTS BANK BUILDING

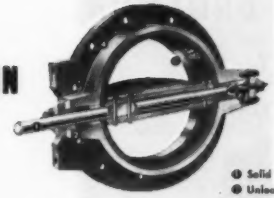
INDIANAPOLIS 4, INDIANA

Reilly COAL TAR PRODUCTS

ARMED Protective Coatings

Sales offices in principal cities

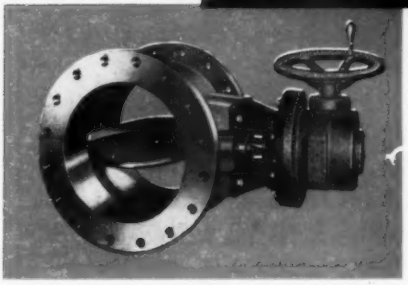
POSITIVE CONTROL OF MATERIALS IN MOTION B-I-F METERS FEEDERS CONTROLS

BUILT-IN  VALVE DEPENDABILITY...

- Solid Stainless Steel Shaft
- Unloaded Stuffing Box
- 90° Shaft Rotation
- Rugged Valve Body
- Unique Reinforced Valve Seat
- Two-Way Thrust Bearing

B-I-F Builders-Providence BUTTERFLY VALVES!

• NO "FREEZING"! • NO LEAKING! • MUCH LESS MAINTENANCE!



Performance-proved in the 25 to 125 psi range, Builders Butterfly Valves are built to AWWA specifications. Non-corrosive metal to rubber seating results in bubble tight closure and free and easy operation even after long periods of inactivity. Shaft rotates only 90° . . . reduces wear and tear on shaft and stuffing box. All types of valve operators available to suit your requirements.

B-I-F Industries

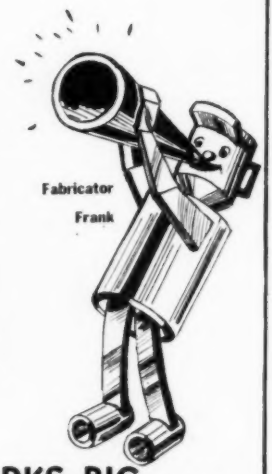
BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

Ask for proof! Request Bulletins 650.20-1 & 650.20-2 for complete design details. Write to **B-I-F Industries, Inc., 388 Harris Avenue, Providence, R. I.**

EVERY BUSINESS INVOLVED IN PURCHASING FABRICATED STEEL PIPE SHOULD HAVE THIS INFORMATIVE BROCHURE IN ITS FILE!

SEND FOR YOUR FREE COPY . . .
IT MAY SAVE YOU MONEY!



MORGAN THINKS BIG, WORKS BIG . . . MAKES YOUR FABRICATION SAVINGS BIG

If there is such a thing as specialization in the fabrication industry, then Morgan's specialty is that of working in big things—for in this virtually unlimited field, Morgan is peculiarly geared, and therefore able to save you money. For instance, municipalities throughout the country have discovered that Morgan is in a position to provide large diameter fabricated steel pipe lined and coated to meet specifications of American Waterworks Association at a fraction of former cost.

Incidentally, it is with real pride that we are able to announce our appointment this year as one of a select group to handle POLYVINYL CHLORIDE PIPE. Our Plastics Division will tell you if this revolutionary product can bring you even more savings!

FOR YOUR FREE BROCHURE ON FABRICATING, WRITE:

Morgan Steel Products, Inc.
CUSTOM STEEL FABRICATORS
Working . . . LARGE AND LARGE SIZE PIPE . . . BINS . . .
. . . SMOKESTACKS . . . HOPPERS . . . BREECHINGS . . .
00 MORS[illegible] AVENUE • CLEVELAND 27, OHIO • Michigan

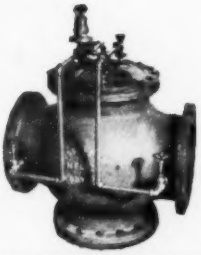
1879—ROSS—1879

Automatic Valves

ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting



SURGE-RELIEF VALVE

Maintains safe operating pressures for conduits, distribution and pump discharge

REDUCING VALVE

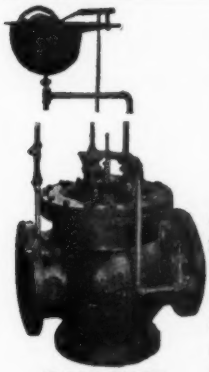
Maintains desired discharge pressure regardless of change in rate of flow

Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

COMBINATION VALVE

A self contained unit with three or more automatic controls

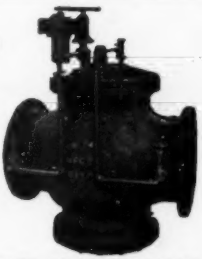
Combination automatic control both directions through the valve.



FLOAT VALVE

Maintains levels in tank, reservoir or basin

1. As direct acting
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.



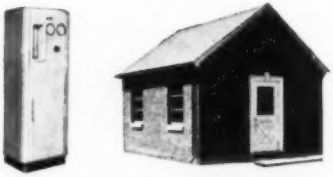
REMOTE CONTROL VALVE

Electric remote control—solenoid or motor can be furnished

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

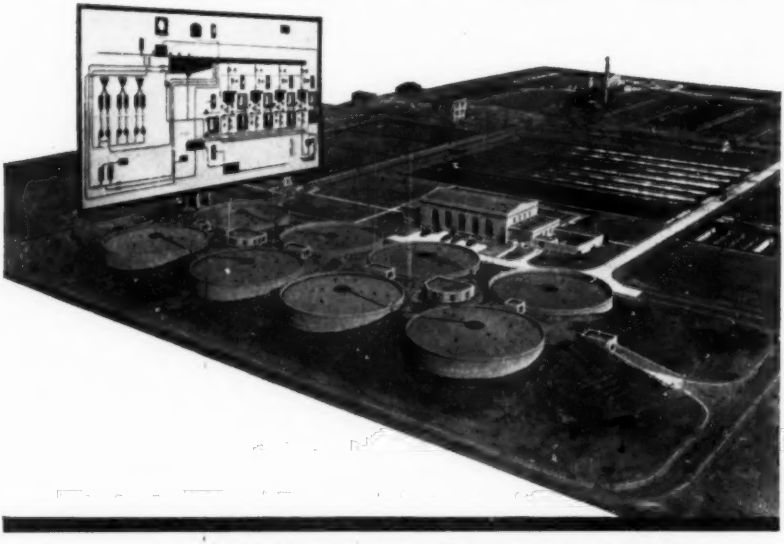
Packing Replacements for all Ross Valves Through Top of Valve

ROSS VALVE MFG. CO., INC., P. O. BOX 593, TROY, N.Y.



from a simple CHLORINATOR in a pumping station

to a complete CONTROL SYSTEM in a multi-million dollar plant



for water, waste, and sewage treatment

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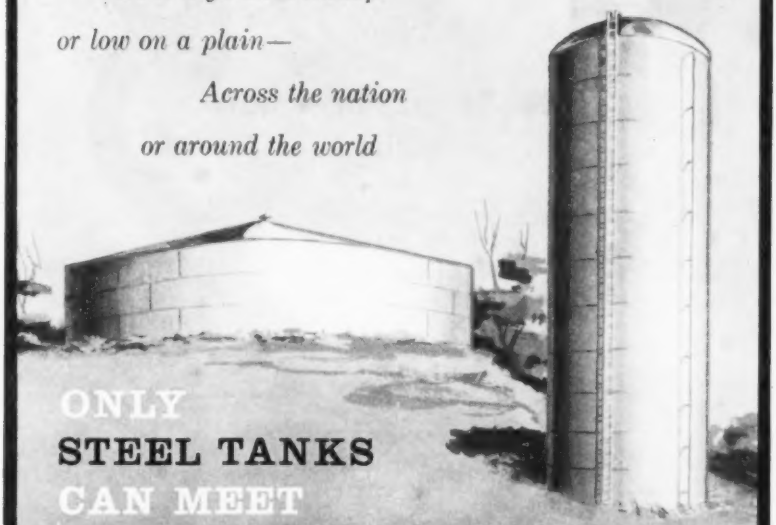

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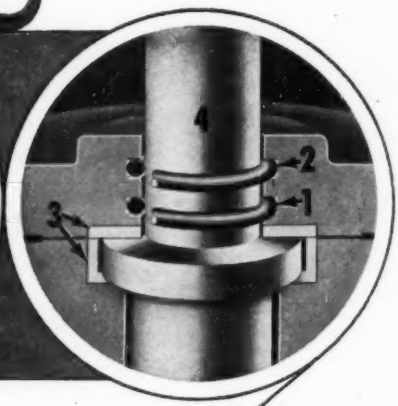
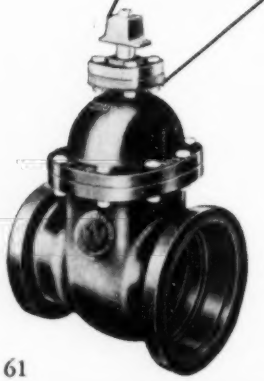


SMITH VALVES WITH "O" RING SEALS



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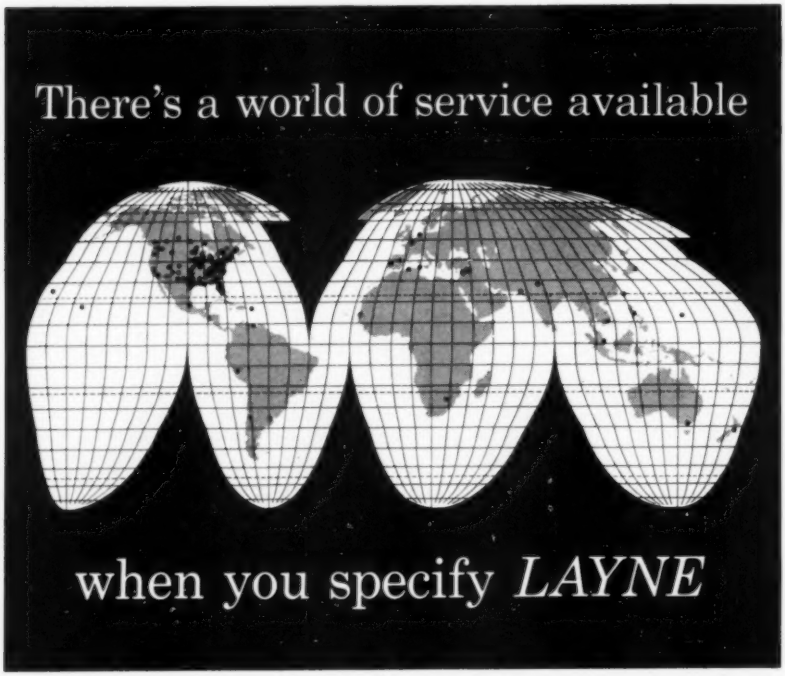

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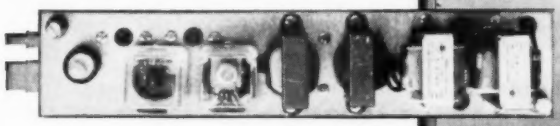
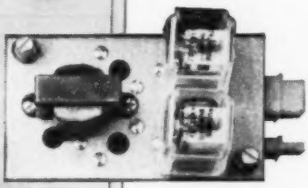


BIPLEX Generator is designed to give two signals, positive dc and 60-cycle ac.



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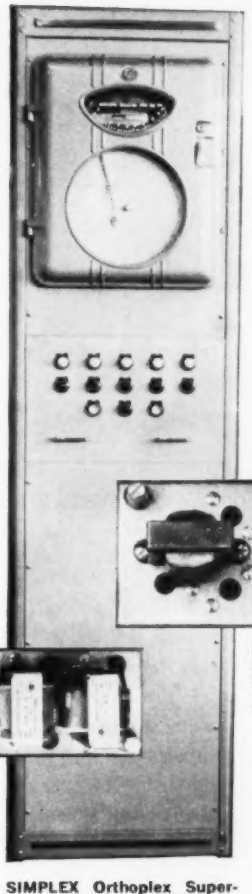

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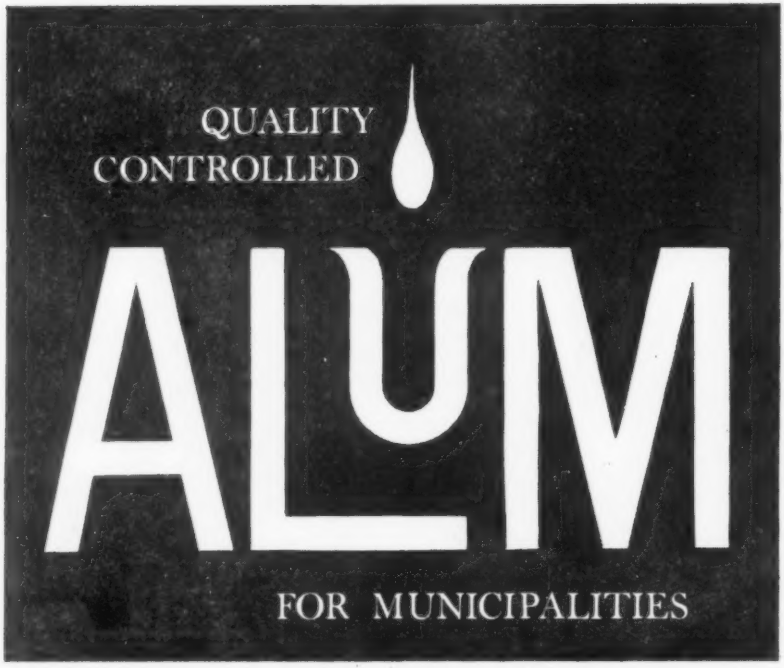

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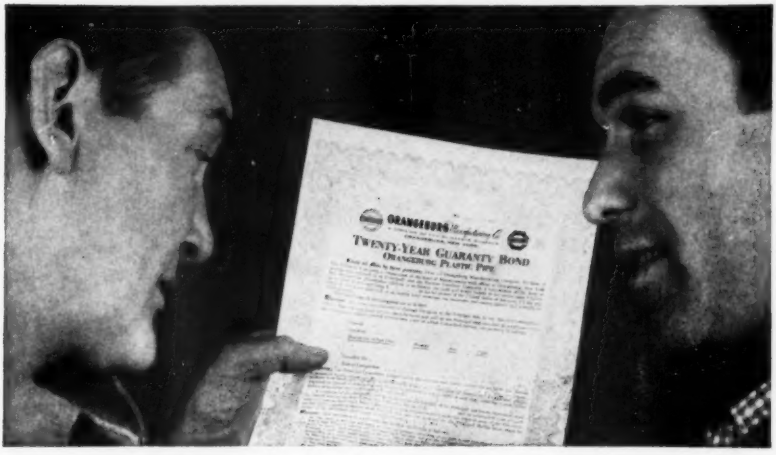

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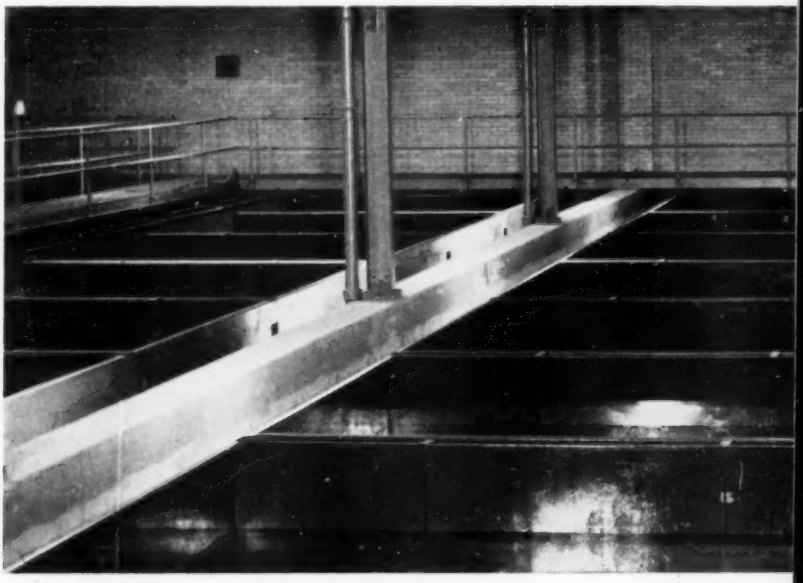

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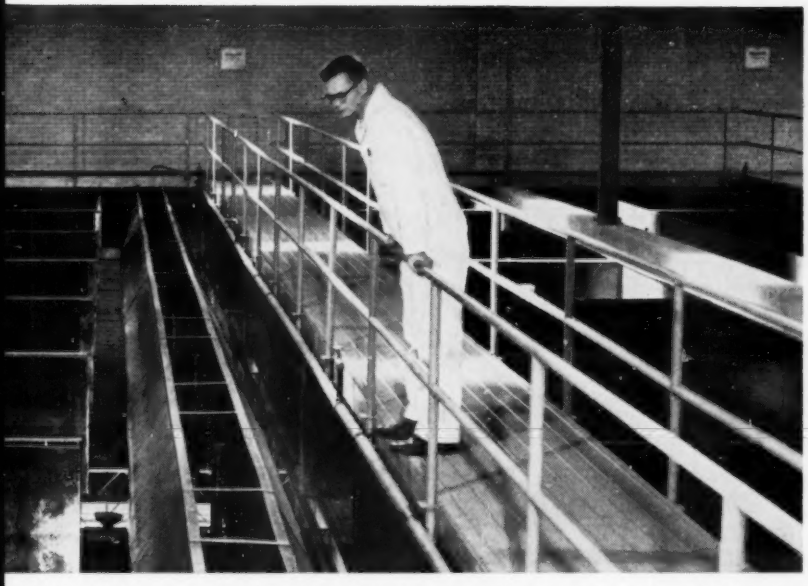

SPACE SAVER: Permutit Horizontal Precipitators take only 25% as much space as would be needed by conventional basins at the Town of Tonawanda Water Treatment Plant, Tonawanda, N. Y.

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If you'd like more information about the efficiencies possible through the use of Permutit Precipitators, write for Bulletin No. 2204C. Or, for a brief introduction to the full line of Pfaudler Permutit equipment for water and waste treatment, ask for the bulletin entitled "An Outline of Modern Water Treating Equipment." Address your inquiries to our Permutit Division, Dept. JA-30, 50 West 44th Street, New York 36, N. Y.

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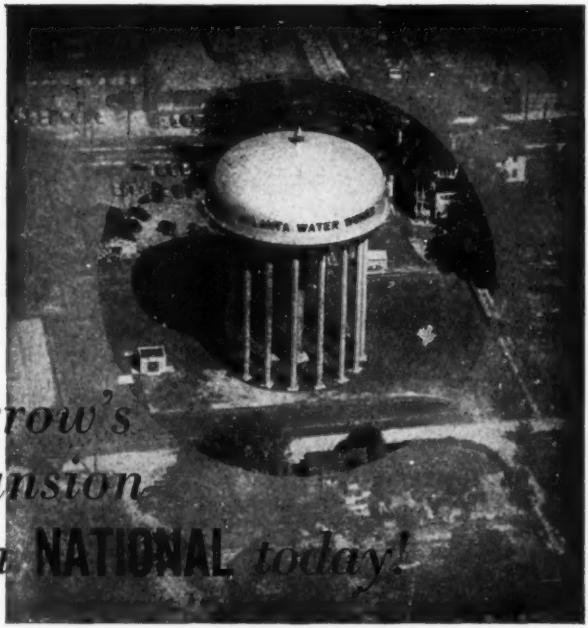
Specialists in FLUIDICS...the science of fluid processes



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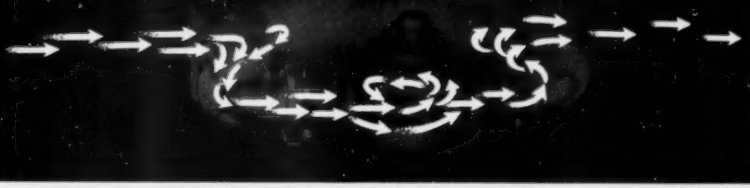
How to Measure Low Flows — or



Full Unimpeded Capacity Flows

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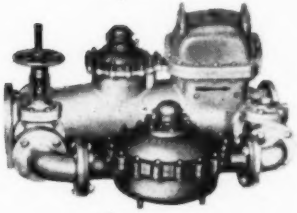

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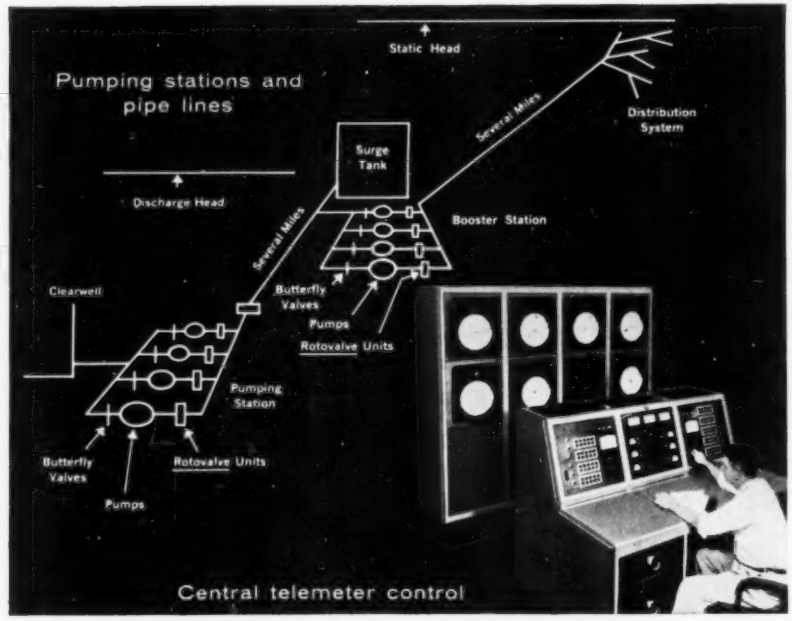

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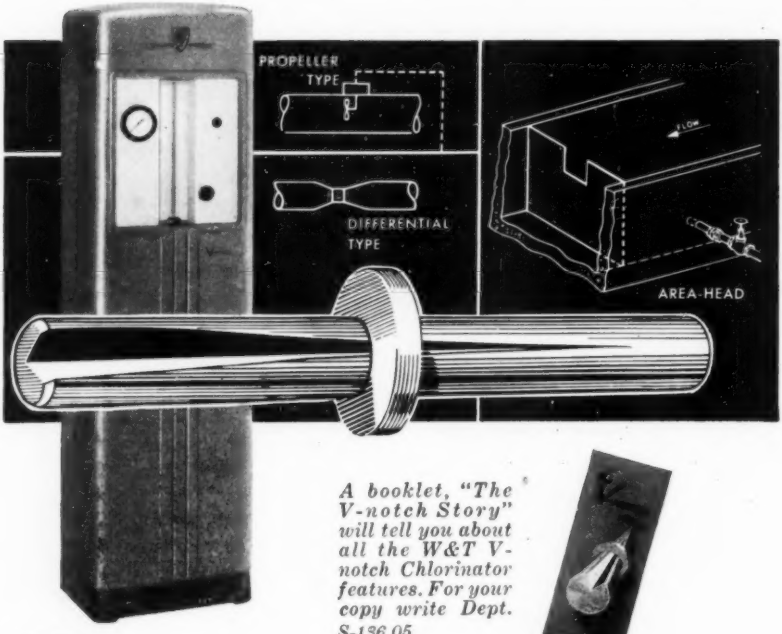

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Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 52 • MARCH 1960 • NO. 3

Significance of Chemical Limits in USPHS Drinking Water Standards

Gene B. Welsh and Jerome F. Thomas

A contribution to the Journal by Gene B. Welsh, San. Engr., Div. of Eng. Services, USPHS, Washington, D.C., and Jerome F. Thomas, Assoc. Prof. of San. Chemistry, Univ. of California, Berkeley, Calif.

THE USPHS drinking water standards were first adopted in 1914 to regulate the quality of water supplied to the public by common carriers engaged in interstate traffic.[1] In 1925, the standards were revised and limits were established for certain chemicals.[2] Additional revisions were made in 1942[3] and again in 1946[4]; the 1946 standards are currently under review by a committee having AWWA representation. Tables 1 and 2 show how the standards have been modified since 1925 to provide the chemical limits being used today.

In their present form, the standards provide two different types of chemical limits: (1) maximum permissible limits for chemicals with known or suspected adverse physiologic effects; and (2) recommended permissible limits for chemicals that are generally nontoxic but have adverse qualities pertaining to color, staining, taste, and odor. In addition, there are alkalinity requirements to prevent overtreatment of the water with chemicals. The physiologic and aesthetic significance of the present chemical limits in the USPHS drinking water standards will be discussed, and certain significant chemicals will be suggested for future addition to the standards.

Chemicals With a Maximum Permissible Limit

Lead

Maximum permissible limit: 0.1 ppm. Lead may be found naturally in water, it may be introduced by industrial effluents, or it may result from the action of water on lead pipes. Lead is foreign to the human body and is considered a cumulative poison. Lead poisoning usually results from continuous consumption over a long period of time, and it is believed that sensitivity to lead increases. It has been reported

that the average adult has a lead intake of 0.3–1.0 mg/day.[5] In excess of 1.0 mg/day, lead is generally absorbed by the body rather than eliminated.[6] The average diet in the United States provides an adequate factor of safety for lead content, but this safety factor may be greatly reduced when the drinking water has a high lead content.[7] For adults, the safe daily intake of lead cannot be stated definitely because of differences in individual sensitivity.

Lead poisoning or plumbism has been known throughout history. For this reason, voluminous literature is available dealing primarily with occupational exposures, although there are some instances where water has been involved. During a New England study involving 253 people, it was found that 84 per cent of 63 lead-poisoning cases were consuming water with a lead content of 0.5 ppm; 14 per cent were using water with a lead content less than 0.5 ppm.[8] It was reported that all the lead-poisoning cases were mild and that most of them had been receiving lead from other sources in addition to drinking water. Other cases of poisoning among humans are reported to have been caused by lead concentrations of 0.14–1.6 ppm in drinking water.[9] The literature also reports an instance where a lead concentration of 0.16 ppm in water apparently had not caused poisoning of humans over a long period of time.[10]

The lead content of natural waters is normally very low, except in the New England area.[8] Samples from 37 systems throughout the United States showed a mean lead content of 0.011 ppm.[11] This would indicate that the 0.1-ppm limit for lead is easily met in most cases. The present limit appears to provide an adequate factor of safety for water users. A tolerance of 7 ppm of lead in food has been established by the government.[12]

Fluoride

Maximum permissible limit: 1.5 ppm. Fluorides may occur naturally in water, or they may be the result of direct contamination from insecticides or industrial effluents. High concentrations of fluorides normally do not occur in surface waters; but in ground waters, a maximum of 30 ppm has been reported, although 4 ppm is normally the maximum.[13]

TABLE 1

Maximum Permissible Chemical Limits—USPHS Drinking Water Standards

Chemical	Standard		
	1925 *ppm*	1942 *ppm*	1946 *ppm*
Lead	0.1	0.1	0.1
Copper	0.2	*	*
Zinc	5.0	*	*
Fluoride	†	1.0	1.5
Arsenic	†	0.05	0.05
Selenium	†	0.05	0.05
Hexavalent chromium	†	0.0	0.05

* Changed to recommended limits after 1925.
† Not included.

In sufficient quantity, fluorides are toxic to humans, with a dose of 250 mg of sodium fluoride giving severe symptoms and 4 g causing death.[14] If an average per capita water consumption of 2 liters/day is assumed, a sublethal dose would require 115 ppm, and a lethal dose would require a concentration of 2,000 ppm.[6]

Extensive epidemiologic data have shown that the presence of fluoride aids in the reduction of dental decay, especially in children. It has been demonstrated conclusively that fluoride con-

centrations between 0.6 ppm and 1.2 ppm in drinking water have a beneficial effect on the structure and resistance to decay of children's teeth.[15] Concentrations of fluoride in excess of 1.5 ppm may cause mild dental fluorosis or "mottled enamel" in 40–50 per cent of children's teeth.[16] According to the studies, mottling caused by these concentrations would be classified as mild, and most cases would not be apparent to the untrained eye. Mottling and disfigurement of the teeth becomes pronounced when the fluoride content exceeds 6 ppm.[13]

It has been reported that fluoride concentrations of less than 5 ppm are almost completely excreted, but at higher concentrations about half is retained by the body.[17] Only when the fluoride content exceeds 5–6 ppm will its prolonged use give rise to detectable changes, and then only in the most susceptible persons.[18] It has been reported that adults may safely drink 2 gal/day of water containing 10 ppm of fluoride.[19] In view of the above, the 1.5-ppm maximum permissible limit in the drinking water standards appears to provide an ample safety factor.

Arsenic

Maximum permissible limit: 0.05 ppm. Arsenic compounds may occur naturally in water, or they may be the result of direct contamination from insecticides, weed killers, and industrial effluents. Small amounts of arsenic are normally found in body tissue, but excessive amounts are considered very toxic to man. The federal government and many states have established a maximum limit of 3 ppm for arsenic trioxide residue on market products.[12] The US Food and Drug Administration permits 1.43 ppm of arsenic in food.[20]

Chronic arseniasis is of slow onset and may not become apparent for years. It is usually characterized by small eruptions on the hands and feet, sometimes developing into cancer. In water taken over a long period of time, arsenic concentrations of 0.21–1.4 ppm have been reported as poisonous to humans.[21] Other literature reports that concentrations up to 0.2 ppm are safe for human consumption; in fact, a 1.0-ppm concentration in drinking water has been consumed for several months with no apparent ill effects.[6] That the ingestion of small amounts of arsenic is not a serious physiologic hazard has been shown by Neal and his coworkers, who studied exposures to lead arsenate sprays.[22]

In view of the fact that 0.21 ppm is the lowest concentration recorded as being poisonous to man, the drinking water limit of 0.05 ppm for arsenic appears to provide adequate protection to water users.

TABLE 2

Recommended Chemical Limits—USPHS Drinking Water Standards

Chemical	Standard		
	1925 *ppm*	1942 *ppm*	1946 *ppm*
Copper	*	3.0	3.0
Zinc	*	15.0	15.0
Iron and manganese (combined)	0.3†	0.3	0.3
Magnesium	100	125	125
Chloride	250	250	250
Sulfate	250	250	250
Phenolic compounds (in terms of phenol)	*	0.001	0.001
Total solids	1,000	500‡	500‡

* Not included.
† Limit for iron only, manganese not included.
‡ Total solids of 1,000 ppm may be permitted.

Selenium

Maximum permissible limit: 0.05 ppm. Selenium is found in some natural waters, or it may be introduced into water as a constituent of industrial wastes. In certain areas, selenium concentrations of 1–6 ppm may be found in natural soil.

Selenium is very toxic to animals, its effects somewhat resembling those of arsenic.[5] Selenium poisoning ("alkali disease" or "blind staggers") in animals has been reported in areas where the vegetation contained as little as 1 ppm of selenium, although 3 ppm is considered a safe tolerance limit.[14] Where selenium poisoning of livestock is common, the toxic effect appears to be very closely associated with the consumption of high concentrations of selenium in food rather than in water.[23] It is interesting to note that arsenic, which is very toxic, has been used to counteract selenium poisoning in animals.[12]

It is widely believed that selenium is very toxic to man, although proof of human injury is meager, and definite symptoms of selenium poisoning have not been identified.[14, 21] Studies in South Dakota, Nebraska, and Wyoming, where selenium is present, have shown that the hazard due to the presence of selenium in water is of secondary importance compared to the hazard from its occurrence in food.[23, 24] The studies indicated that selenium concentrations in water were about 0.2 ppm; in food, about 5 ppm. It is believed that there may be some correlation between dental decay and the selenium content of fluoride-bearing waters, with the selenium being antagonistic toward the beneficial effects of the fluoride.[25]

Even though selenium concentrations in water appear to be secondary to those in food, they cannot be ignored. The possibility that water may contain toxic doses of selenium or may be associated with possible cases of selenium poisoning has led to the established maximum permissible limit.

It is believed that the present limit in the drinking water standards of 0.05 ppm for selenium is satisfactory.

Hexavalent Chromium

Maximum permissible limit: 0.05 ppm. Chromium is usually not present in natural waters, but it may be introduced by various industrial effluents. The salts of trivalent chromium are not considered to be physiologically significant or harmful.[21] The salts of hexavalent chromium, however, are classified as irritants, owing to their corrosive action on the intestinal tract and the skin.[6] It has been reported that hexavalent chromium is about 100 times more toxic than trivalent chromium, and that 0.1 ppm of hexavalent chromium in drinking water may be quite harmful.[20, 26]

Recent observations indicate that the physiologic effect of hexavalent chromium may not be as serious as originally suspected. One case has been reported where a family used well water containing hexavalent chromium wastes for over 3 years with no apparent ill effects.[27] When first discovered, the hexavalent chromium concentration in the water was 1.0 ppm, and later analysis showed as much as 25 ppm. Physical examinations of the entire family revealed no abnormal conditions. Other reports indicate that as much as 10 ppm of potassium dichromate in drinking water for 15 days caused nausea; 2.5–3.5 ppm caused no apparent ill effect. These two cases certainly do not justify an immediate change in the maximum permissible limit for hexavalent chromium, but they do indicate the need for more information.

The present limit of 0.05 ppm for hexavalent chromium appears to provide an adequate factor of safety for water users, especially in view of the fact that analyses have shown chromium concentrations in milk as high as 0.5 ppm.[5]

Other Chemicals

In addition to those chemicals for which maximum permissible limits have been established, the drinking water standards state that salts of barium, heavy metal glucosides, or other substances with deleterious physiologic effects shall not be added to the water for treatment purposes. The effect of barium in drinking water is not yet fully understood, but it is believed that all soluble barium salts are very toxic to man.[14, 20] Many authorities feel that limitations on the addition of heavy metal glucosides or other physiologically deleterious materials for treatment purposes are justified.

Chemicals With a Recommended Limit

Copper

Recommended limit: 3.0 ppm. Copper salts usually occur in natural waters in trace amounts. The presence of these salts may also be the result of corrosive action of water on copper or brass tubing, industrial effluents, or the use of copper compounds for undesirable plankton control.

The role of copper in drinking water is not clearly established, but it is generally considered to be of little, if any, significance to public health. Traces of copper are found in practically all plant and animal life, and it is believed that small amounts are essential for nutrition. The copper requirement for adult humans is reported to be about 3 mg/day; small amounts of copper in water may help to fulfill this requirement.[28] Chronic copper poisoning in humans has not been proved, even among people in the copper industry who have absorbed sufficient copper for their skin and hair to become green.[19, 28]

Copper is not a cumulative poison like lead or mercury. Most of the copper intake is excreted by the body. It is believed that doses of 100 mg/day may be injurious, because they irritate the intestinal tract.[6] In fact, copper salts have an emetic effect; it is therefore difficult to retain sufficient quantities in the body to cause chronic illness.[5]

Copper concentrations of 1.5 ppm may give water a noticeable metallic taste, and 5 ppm may make the water unpalatable.[5, 6] It has been reported that a person would have to drink 8 gal of water containing 3 ppm of copper to get as much copper as from one dozen oysters.[29] In view of this, the recommended limit of 3.0 ppm seems to provide an adequate factor of safety.

Most authorities feel that copper in drinking water is not a public health hazard because the water becomes distasteful before dangerous toxic concentrations are reached. For this reason, the copper limit must be attributed primarily to aesthetic considerations.

Zinc

Recommended limit: 15 ppm. In most surface and ground waters, zinc usually occurs in trace amounts, so that significant concentrations are usually the result of industrial effluents or mine wastes.

Even though high concentrations of zinc have no known or apparent physiologic effect, they are undesirable in

drinking water for aesthetic reasons. Readily soluble salts of zinc have an unpleasant, astringent taste that can be detected in water well below the danger limit.[30] It has been reported that water supplies containing up to 40 ppm of zinc have been used with no apparent ill effect,[21] but 30 ppm usually gives the water a milky appearance, and 25–40 ppm may impart a metallic taste.[31] Concentrations of 5 ppm have been characterized by the formation of a greasy film when water is boiled.[32] It has also been reported that waters containing relatively high amounts of zinc should not be used in making acid drinks because of the possible formation of zinc citrate, a poisonous compound.[20]

It appears that the recommended limit of 15 ppm for zinc is based primarily on aesthetic rather than physiologic considerations.

Iron and Manganese

Recommended combined limit: 0.3 ppm. Iron and manganese may occur together in natural waters, or they may result from industrial effluents or mine wastes. Manganese is more common in ground water than in surface water, and iron may occur in either source.

It has been estimated that the average daily intake of iron and manganese in adults is about 12 mg and about 4 mg, respectively, both obtained primarily from food.[5] In view of this, the amounts normally present in drinking water must be considered of little toxicologic significance.

Waters containing as much as 0.5 ppm of iron and manganese have been used with no apparent adverse effects.[5] The literature, however, reports one instance in Japan when sixteen people were poisoned, resulting in three deaths, by drinking well water containing high concentrations of zinc and manganese.[9] In this particular instance, the water was contaminated by metallic wastes that were buried near the well.

Iron has not been associated with known adverse physiologic effects, but it is recognized that water supplies containing iron are subject to difficulties from certain bacteria. One incident is reported where a very large quantity of iron bacteria, with clumps up to 3–4 in. in diameter, was discharged by a well.[33] Other reports tell of bacterial growths that practically sealed off the flow of water in pipes.

Iron and manganese are undesirable from an aesthetic standpoint, as it is well known that they tend to stain laundry and plumbing fixtures and tend to cause deposits on food during cooking. Iron usually produces a yellowish or reddish-brown stain; manganese produces a gray or black stain.[34] In addition, concentrations greater than 0.5–1.0 ppm may impart a metallic taste to water.

The recommended limit of 0.3 ppm for iron and manganese combined, apparently is based on aesthetic and taste considerations rather than on potential physiologic effect.

Magnesium

Recommended limit: 125 ppm. Magnesium is one of the most common elements, and may be found readily in natural water sources. It may also be introduced by industrial effluents from various processes.

It is known that high concentrations of magnesium salts may have a laxative effect, especially on new users of a supply. It is also known that the human body usually develops a tolerance to magnesium salts and that water supplies with relatively high magnesium concentrations have been used over a long period of time with no adverse effect. Magnesium limits

of 50–200 ppm have been proposed for domestic water supplies.[35, 36] These proposed limits were based on specific considerations and have not been widely accepted.

It is generally agreed that magnesium is not a public health hazard in drinking water, because it imparts a very unpleasant taste to the water before toxic concentrations are reached.[20] The limit of 125 ppm for magnesium must be justified on the basis of aesthetic considerations and minimization of possible physiologic effects.

Chlorides

Recommended limit: 250 ppm. Chlorides are found in practically all natural waters. They may be of natural origin or result from contamination due to salts from agriculture, sewage, or industrial effluents. It is believed that the source of chloride in drinking water may be a more important factor than the concentration. A sudden increase in chloride content may be a possible indication of pollution.

In general, chlorides in drinking water do not cause physiologic reactions until concentrations approaching those of sea water are reached. It has been reported that high concentrations of chlorides may be injurious to people with heart and kidney diseases, but up to 4,000 ppm has no effect on the health of normal persons.[37] Chlorides in water may impart a salty taste at concentrations of 100 ppm, although in some waters 700 ppm may not be noticeable.[6] There is some indication that these variations are the result of the combination of chlorides and other salts.

Human tolerance to chlorides varies with climate and physical exertion. Chlorides lost through perspiration normally are replenished by food or drinking water. In fact, salt is often added to the drinking water in hot, dry areas to help maintain the chloride content in the human body. Chloride concentrations as high as 600 ppm in drinking water are commonly used in the southwestern United States with no apparent adverse effect.[6]

It has been reported that the presence of chlorides in water may result in disadvantages other than physiologic, because chlorides may accelerate corrosion in pipes, boilers, and other fixtures.[9] Concentrations of 20–100 ppm have been reported to be corrosive under certain conditions.[38]

In view of the fact that there are no known physiologic reactions from chloride concentrations as high as 4,000 ppm, the recommended limit of 250 ppm must be for reasons of potability rather than health.

Sulfates

Recommended limit: 250 ppm. Sulfates may occur naturally in waters as a result of the leaching of gypsum and other common minerals. They may result also from the oxidation of organic matter in the sulfur cycle or from the discharge of numerous industrial effluents.

Sulfates are significant in that they are associated with a laxative effect when they occur in high concentrations. A cathartic dose is considered to be in the range of 1,000–2,000 ppm, well beyond the concentrations normally found in drinking water. It has been reported that the taste thresholds of sulfate salts range from 200 ppm of sulfate when combined with sodium to 600 ppm of sulfate when combined with magnesium.[39] This indicates that the water would have a very undesirable taste at concentrations high enough to have a laxative effect.

Sulfate concentrations up to 1,000 ppm are considered harmless.[39] Wa-

ters with a sulfate content well above the recommended limit of 250 ppm have been used commonly and constantly with no adverse effect.[6] The 250-ppm limit evidently was based on factors other than physiologic effect, most likely on considerations of taste and minimization of cathartic effects.

Phenols

Recommended limit: 0.001 ppm, in terms of phenol.

Phenolic compounds rarely occur naturally in water, but result mainly from pollution by industrial wastes.

Normal concentrations of phenol in drinking water would not be significant were it not a fact that they cause objectionable tastes and odors when waters are chlorinated. It has been reported that a minimum concentration of 0.001 ppm of phenol will produce objectionable tastes and odors in chlorinated water,[35, 40] but 0.01 ppm is required before objectionable tastes and odors are produced in unchlorinated water.[41] It is unlikely that harmful concentrations of phenol could be consumed in drinking water. Taste and odor qualities would discourage the consumption of such high concentrations.

It appears evident that the recommended limit for phenols is based on taste and odor considerations rather than on potential health hazard due to physiologic effect.

Total Solids

Recommended limit: 500 ppm. If water with this limit is not available, a total solids content of 1,000 ppm may be permitted.

Total solids is a general measure of the mineral and residue characteristics of the water. There is no known harmful physiologic effect attributed to water with a high total solids content. In most instances, a high total solids content results from high concentrations of sulfate, chloride, or other chemical compounds in the water.

Some authorities believe that the total solids limitation was based on the fact that people who are accustomed to drinking soft water may suffer some physical discomfort when they consume water with a high mineral content.[6] In any event, the limitation appears to provide adequate protection.

Alkalinity

Recommended limits for chemically treated waters: (1) the phenolphthalein alkalinity should not be greater than 15 ppm, plus 0.4 times the total alkalinity; (2) the normal carbonate alkalinity should not exceed 120 ppm; and (3) if the excess alkalinity is the result of chemical treatment, the total alkalinity should not exceed the hardness by more than 35 ppm.

These recommended limits were designed to prevent overtreatment of water with chemicals for softening or corrosion control, rather than for use with natural waters. There has been no evidence that moderate alkalinity is detrimental to human health. Alkalinity is generally associated with high pH, hardness, and excessive amounts of dissolved solids, all of which may have some deleterious effect. Caustic waters frequently have a flat taste, and 50–100 ppm of caustic alkalinity may produce a distinct lime taste.[6]

The recommended alkalinity limits for chemically treated waters are interrelated with the pH value. In general, they imply that total alkalinity (as $CaCO_3$) should not exceed 400 ppm for pH values between 8.0 and 9.6, and 160 ppm for a pH value of 10.6. These values are suggested guides to treatment rather than limits based on proved physiologic effects due to alkaline compounds.

Chemicals for Which Limits Should Be Added

It is generally agreed that there are at least four pollutants of public health significance not presently included in the standards. It is realized that there are others that could be considered, but only cadmium, cyanide, nitrate, and radioactivity will be discussed. All four of these have suspected or potential physiologic effects.

Cadmium

Elemental cadmium is insoluble and generally not found in water. Cadmium ions, however, may be present in natural waters, and cadmium salts may be introduced into water with certain industrial wastes.

The use of cadmium-plated food and drink containers is forbidden by many health agencies. This prohibition resulted from outbreaks of cadmium poisoning due to the ingestion of acid food or drink that had been in contact with cadmium-plated containers. In general, cadmium is considered toxic to man; however, chronic or cumulative poisoning has not been observed among human beings. Most authorities agree that further study of the possible physiologic or toxicologic effects of cadmium in drinking water is needed.[13, 14]

As little as 14.5 mg of cadmium taken orally has caused nausea and vomiting; but as much as 326 mg has not caused death.[42] Human beings have become sick from cadmium concentrations of 13–530 ppm in various items of food and drink.[14]

In Russia, which is one of the few countries that has established chemical limits for drinking water, the maximum permissible limit for cadmium is 0.1 ppm.[42] It appears that this value may be a satisfactory limit for use in the United States, until further experience and knowledge provide a more feasible limit.

Cyanides

Cyanides normally do not occur in natural waters, but usually result from an industrial waste effluent or from the use of insecticides or rodenticides. Most of the cyanide in water is in the form of hydrogen cyanide, a very deadly poison. When cyanide compounds are added to water in dilute concentrations, the cyanide ion reacts with the hydrogen ion to form hydrogen cyanide. It is not known fully which is the more toxic, cyanide or hydrogen cyanide; however, it has been reported that in a pH range of 6.0–8.5 there is no appreciable difference between the toxicity of the two.

It has been reported that more than 37.8 mg of cyanide is fatal, but ½ gal of water containing 10 ppm of cyanide may be consumed safely by adults.[19] For hydrogen cyanide ingestion by man, the average fatal dose is reported to be 50–60 mg.[13]

In Russia, the maximum permissible limit of cyanides is given as 0.2 ppm.[43] This would appear to be a reasonable limit for use in the United States, until more knowledge and experience are available.

Nitrates

Nitrates are the end product of the aerobic stabilization of organic nitrogen, and as such they may occur in waters that have undergone aerobic treatment processes. In addition, they may result from fertilizers and inorganic industrial wastes. In spite of their many sources, nitrates are seldom abundant in natural surface waters. Well waters, however, may contain high concentrations of nitrate, and as

much as 1,000 ppm has been found in some shallow wells.[37]

Methemoglobinemia in infants, a disease characterized by certain blood changes and cyanosis, may be caused by high nitrate concentrations in water used for preparing infant feeding formulas. This disease generally affects infants less than 6 months old. It is unknown in adults, except for cases of excessive ingestion of certain nitrogen-containing drugs or chemicals. Not all infants are susceptible to nitrate poisoning. Many well waters containing 500 ppm of nitrate nitrogen have not been linked with reported cases of the disease, but most cases of infant methemoglobinemia have been associated with concentrations in excess of 50 ppm nitrate nitrogen. A few cases have been reported for concentrations of 11–40 ppm.[6] Practically all cases have been related to private water supplies in rural areas. Well waters have been involved exclusively, with shallow wells predominating. It is generally agreed that many of the factors associated with infant methemoglobinemia are not fully understood, but in all reported cases there has been a high concentration of nitrate nitrogen in the drinking water.

Although precise concentration limits have not been established, it is generally agreed that water containing more than 10–20 ppm of nitrate nitrogen should not be used to feed infants.[14, 37] A maximum limit of 20 ppm could be used until additional data indicate a more feasible limit.

Radioactive Material

Radioactive substances are a significant public health problem because they are potential pollutants that may be very harmful to health. In liquid forms, radioactive wastes are a potential public health hazard, because continued exposure or ingestion may cause the accumulation of dangerous levels of radiation within the body, leading to drastic changes in the cells and tissues.

Radioactive substances may occur in water from natural deposits, nuclear reactors, or from the ever increasing use of radioisotopes in medicine, research, and industry. Because of their abundance and increased usage, radioactive materials must be considered a potential source of contamination in drinking water.

The biologic effects of all ionizing radiations are not the same; some are more damaging than others. The deleterious effect of radioactive substances in the body varies with the amount, location, kind, duration of exposure, and vital importance of the tissue affected. For these reasons, exact tolerance limits are difficult to establish.

It is generally agreed that all unnecessary exposure to radiation should be avoided. As some exposure is inevitable, maximum permissible concentrations have been established by governmental agencies and technical committees.[44]

Owing to the magnitude of the problem, it can be pointed out here only that radioactive substances are a potential health hazard and that limits should be considered for addition to the drinking water standards. No attempt will be made to suggest specific maximum permissible limits. More authoritative information on this subject is readily available.

Summary

USPHS drinking water standards were first adopted in 1914, but the 1925 revisions provided the first numerical limits for specific chemicals. The most recent modifications were made in 1946 and are still in use. These drinking

water standards have become widely accepted as effective and fair.

The present standards provide maximum permissible limits for lead, fluoride, arsenic, selenium, and hexavalent chromium, because of their known or suspected physiologic effects. In addition, recommended permissible limits are provided for copper, zinc, iron and manganese, magnesium, chlorides, sulfates, phenolic compounds, and total solids, because of their potential taste, odor, staining properties, or indirect physiologic effect. Certain alkalinity requirements are also provided to prevent overtreatment of water with chemicals.

The present limits appear to be satisfactory; however, consideration should be given to providing limits for cadmium, cyanides, nitrates, and radioactive material. All four of these water pollutants are suspected of potential physiologic effects.

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Status of Fluoridation in the United States and Canada, 1958

Task Group Report

A report of Task Group 2620 P—Fluoridation Materials and Methods, submitted by Robert S. Phillips (Chairman), Asst. Supt., Water Dept., Charlotte, N.C. Other members of the task group are R. L. Derby, H. A. Faber, A. E. Griffin, L. E. Harper, W. L. Harris, F. J. Maier, O. J. Muegge, R. W. Ockershausen, R. C. Pickard, F. S. Taylor, H. W. Tracy, D. B. Williams, and J. C. Zufelt.

THE use of fluoridated water supplies in North America continued to increase steadily during the 2 years, 1957 and 1958, since Task Group 2620 P—Fluoridation Materials and Methods made its last report.[1] By the end of 1958, more than 36,000,000 people were drinking water provided by 1,000 systems that were adding controlled amounts of fluorides to water supplies (Table 1 and Fig. 1).

In the United States, this growth of fluoridation, although steady in the past few years, has not been as spectacular as during the period 1950–53. Canada, on the other hand, has shown a relatively more consistent growth trend since 1954. The decline in the rate of increase of fluoridation in the United States has caused Secretary Flemming, of the Department of Health, Education, and Welfare, to conclude that "the proportion of the population not benefiting from this remarkable health measure is actually increasing."[2] On the other hand, in communities where fluoridation is practiced, there appears to be a better acceptance of the procedure, for only two water systems serving 15,130 people discontinued fluoridation in 1958. When this is compared to the 20 systems serving more than 1,000,000 people which discontinued fluoridation in 1954, the 1958 record becomes increasingly impressive. Not since 1951 have there been fewer supply systems, serving fewer people, that discontinued fluoridation (Table 2).

Most of the increase (78 per cent) during the past 2 years has been in communities with populations of less than 25,000. By the end of 1958, nearly 40 per cent of all communities in the United States with populations of 10,000 or more were using fluoridated water. For comparison, less than 30 per cent of the communities of 10,000 or more people were using fluoridated water in 1956.[1] Even in the smallest population group—1,000–2,499—there were 338 communities using fluoridated water by the end of 1958 (Fig. 2, Tables 3 and 4).

Fluoridation Chemicals

Sodium silicofluoride continues to be the chemical used by most water systems, large and small. More than 50 per cent of all systems in the United

TABLE 1

*Increase in Use of Fluoridated Supplies in the United States and Canada, 1945–1958**

End of Year	United States			Canada	
	Number of Systems Using Fluoridation	Number of Communities Served	Population Served	Number of Systems Using Fluoridation	Population Served
1945	3	6	231,920	1	51,100
1946	8	12	332,467	1	51,100
1947	11	16	458,748	1	51,100
1948	13	24	581,683	1	51,100
1949	29	46	1,062,779	1	51,100
1950	62	96	1,578,578	1	51,100
1951	171	339	5,020,502	1	51,100
1952	353	717	13,644,677	6	161,400
1953	482	965	17,200,031	8	213,350
1954	572	1,146	21,597,065	9	224,350
1955	668	1,299	25,224,031	19†	806,730
1956	764	1,519	31,979,966	25†	952,480
1957	872	1,635	33,806,228	33	1,018,330
1958	960	1,778	35,240,253	41	1,075,685

* Revised data furnished by USPHS.
† Toronto Township (23,000 people) began fluoridation during 1955, and discontinued it during 1956. The 1956 figure does not include Toronto Township.

TABLE 2

*Fluoridation Installations in the United States Instituted, Discontinued, and Reinstituted, 1945–1958**

Year	Fluoridation Instituted†		Fluoridation Discontinued‡		Fluoridation Reinstituted	
	Number of Supply Systems	Population Served	Number of Supply Systems	Population Served	Number of Supply Systems	Population Served
1945	3	231,920				
1946	5	100,547				
1947	3	126,281				
1948	2	122,935				
1949	16	481,096				
1950	34	532,349	1	16,550		
1951	110	3,454,824	1	12,900		
1952	187	8,796,847	5	172,672		
1953	134	3,440,504	7	51,616	2	166,466
1954	108	5,462,975	20	1,069,875	2	3,934
1955	112	4,007,034	18	394,040	2	13,972
1956	105	6,905,648	13	188,082	4	38,369
1957	109	1,952,142	4	192,220	3	66,340
1958	90	1,449,155	2	15,130	0	0
Total		37,064,257		2,113,085		289,081

* Revised data furnished by USPHS.
† Total, whether or not discontinued.
‡ Total, whether or not reinstituted.

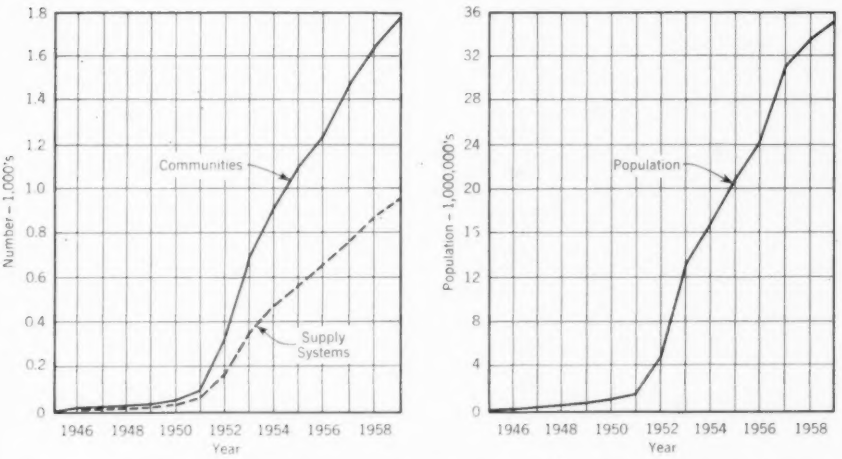

Fig. 1. Number of People, Communities, and Supply Systems in the United States Using Fluoridated Water, 1945–1958

By the end of 1958, about 35,000,000 people were drinking fluoridated water supplied by 960 systems.

States, which serve 20,588,802 people, are adding sodium silicofluoride to their supplies.

Sodium fluoride is used by a large number of the smaller systems; the use of fluosilicic acid is growing among small and large communities. Only two communities use calcium fluoride, and no ammonium fluosilicate installations have been instituted since 1954 (Tables 5–7 and Fig. 3).

During 1958, some water officials experienced difficulty in obtaining an adequate supply of fluosilicic acid, and an AWWA survey found the supply to be critical. Ample supplies of both sodium silicofluoride and sodium fluoride were reported in the same survey.[8]

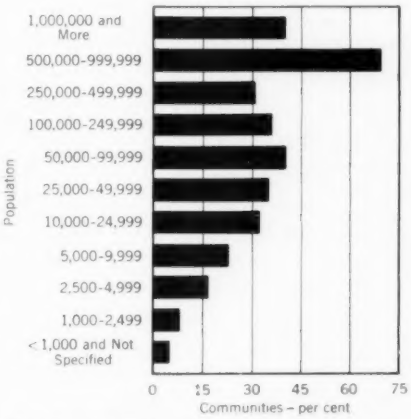

Fig. 2. Percentage of United States Communities Using Fluoridation, According to Community Population—Dec. 31, 1958

By the end of 1958, nearly 40 per cent of all communities in the United States with populations of 10,000 or more were using fluoridated water.

Feedability Index

The tentative standard for sodium silicofluoride (AWWA B702) is under

TABLE 3

*Use of Fluoridation in United States Communities, by Community Population—Dec. 31, 1958**

Population Segment	Number of Communities†	Communities Using Controlled Fluoridation	
		Number	Percentage
1,000,000 and more	5	2	40.0
500,000–999,999	13	9	69.2
250,000–499,999	23	7	30.4
100,000–249,999	65	23	35.4
50,000– 99,999	126	50	39.7
25,000– 49,999	252	87	34.5
10,000– 24,999	778	248	31.9
5,000– 9,999	1,176	268	22.8
2,500– 4,999	1,846	305	16.5
1,000– 2,499	4,296	*338	7.9
<1,000 and not specified	9,968	441	4.4
Total	18,548	1,778	9.6

* Data furnished by USPHS.
† Source: Statistical Abstract. US Bureau of the Census, Department of Commerce, 1956.

study by a subcommittee of Task Group 2620 P. One of the aspects of the study concerns "feedability" of the chemical as presently specified. The subcommittee has tentatively proposed the following "feedability index" formula:

$$F = 100 - (A + B + 10C)$$

in which F is the feedability index; A, the percentage of sodium silicofluoride retained on a 100-mesh sieve; B, the percentage of sodium silicofluoride passing a 325-mesh sieve; and C, the percentage of moisture in sodium silicofluoride. Further, the subcommittee suggests that chemicals with a feedability index greater than 80 would have good feedability; less than 80, poor feedability. The industry is requested to test the validity of this formula and submit to the task group comments or experiences regarding its use.

TABLE 4

*Ownership and Authorization for Fluoridation in the United States, According To Community Population—Dec. 31, 1958**

Population Segment	Number of Communities	Ownership			Authorization			
		Public	Private	Other and Not Specified	Governing Body Alone	Referendum	Utilities Commission	Other and Not Specified
1,000,000 and more	2	2	0	0	2	0	0	0
500,000–999,999	9	9	0	0	8	1	0	0
250,000–499,999	7	6	1	0	7	0	0	0
100,000–249,999	23	19	3	1	19	2	0	2
50,000– 99,999	50	43	6	1	43	4	0	3
25,000– 49,999	87	77	9	1	76	3	2	6
10,000– 24,999	248	215	26	7	209	20	5	14
5,000– 9,999	268	222	43	3	227	14	7	20
2,500– 4,999	305	253	43	9	259	12	6	28
1,000– 2,499	338	288	43	7	287	13	10	28
<1,000	221	167	53	1	195	11	5	10
Not specified	220	181	28	11	156	18	28	18
Total	1,778	1,482	255	41	1,488	98	63	129

* Data furnished by USPHS.

New York University Study

During 1957–58, New York University prepared, for the New York State Department of Health, a detailed study of water fluoridation practices in twenty major cities in the United States.[4] The conclusions reached in this study are important, because they answer a number of questions about fluoridation that are asked from time to time by individuals and groups. Among the more important conclusions reported were these:

1. "All engineering problems that occur in the handling of fluorides can be adequately solved. . . ."

2. "Chemical composition of water to which fluoride-bearing chemical is added is not apparently an important factor to be considered when placing fluoride into solution."

3. "Neither the length of line, period of flow, age of pipe, nor materials to which water is exposed affect significantly the average fluoride ion content in distribution systems."

4. Records show "no evidence of feedback of concentrations of fluoride ion from such postulated sources as pipe coatings, tuberculation, treatment sludges, and storage-reservoir sediments."

5. "There is no evidence that the handling of fluoride-bearing chemicals presents an employee health hazard that cannot be controlled."

TABLE 5

*Chemical and Feeder Used in United States Communities With Fluoridated Water, According to Population Served—Dec. 31, 1958**

Population Served	Number of Supply Systems	Chemical							
		Sodium Fluoride		Sodium Silicofluoride		Fluosilicic Acid	Ammonium Fluosilicate	Calcium Fluoride	Other and Not Specific
		Type of Feeder							
		Dry	Solution	Dry	Solution	Solution	Solution	Solution	
1,000,000 and more	5			2		3			
500,000–999,999	9			8		1			
250,000–499,999	13	2		10					
100,000–249,999	32	6	1	20		3			2
50,000– 99,999	39	5		28		5			1
25,000– 49,999	68	13	1	46	2	2	1		3
10,000– 24,999	205	21	22	134	8	9			11
5,000– 9,999	186	28	34	103	2	16			3
2,500– 4,999	175	15	45	77	4	19	4	2	9
1,000– 2,499	159	9	86	36	4	21			3
<1,000	58	1	46	2	3	6			
Not specified	11	1		1					9
Total	960	101	235	467	24	85	5	2	41

* Revised data furnished by USPHS.

TABLE 6

*Annual Cumulative Numbers of Supply Systems in the United States Using Fluoridated Water, According to Chemical and Type of Feeder Used, 1945–1958**

Year	Total Number of Supply Systems	Chemical							
		Sodium Fluoride		Sodium Silicofluoride		Fluosilicic Acid	Ammonium Fluosilicate	Calcium Fluoride	Other and Not Specified
		Type of Feeder							
		Dry	Solution	Dry	Solution	Solution	Solution	Solution	
1945	3	2	1						
1946	8	4	3	1					
1947	11	5	4	2					
1948	13	5	5	2		1			
1949	29	9	10	8		1			1
1950	62	12	21	24		3			2
1951	171	29	43	78		18	1		2
1952	353	50	86	177	3	33	2		2
1953	482	60	121	247	7	39	3		5
1954	572	68	136	300	7	48	5		8
1955	668	81	163	336	13	57	5	1	12
1956	764	92	185	376	15	63	5	1	27
1957	872	99	217	422	17	71	5	1	40
1958	960	101	235	467	24	85	5	2	41

* Revised data furnished by USPHS.

TABLE 7

*Annual Cumulative Population in the United States Served Fluoridated Water, According to Chemical Used, 1945–1958**

Year	Total Population	Chemical					
		Sodium Fluoride	Sodium Silicofluoride	Fluosilicic Acid	Ammonium Fluosilicate	Calcium Fluoride	Other and Not Specified
1945	231,920	231,920					
1946	332,467	315,747	16,720				
1947	458,748	428,028	30,720				
1948	581,683	430,963	30,720	120,000			
1949	1,062,779	840,225	96,274	120,000			6,280
1950	1,578,578	990,764	376,211	200,774			10,829
1951	5,020,502	1,386,453	3,316,999	302,109	4,112		10,829
1952	13,644,677	2,535,332	9,350,957	1,740,447	7,112		10,829
1953	17,200,031	3,007,445	12,181,735	1,815,939	9,612		185,300
1954	21,597,065	2,758,999	14,489,616	4,038,105	59,621		250,724
1955	25,224,031	3,528,671	16,374,030	4,980,228	59,621	2,700	278,781
1956	31,979,966	3,689,155	18,243,727	9,574,672	59,621	2,700	410,091
1957	33,806,228	4,004,493	19,399,638	9,616,535	59,621	2,700	723,241
1958	35,240,253	4,075,160	20,588,802	9,777,060	59,621	5,369	734,241

* Revised data furnished by USPHS.

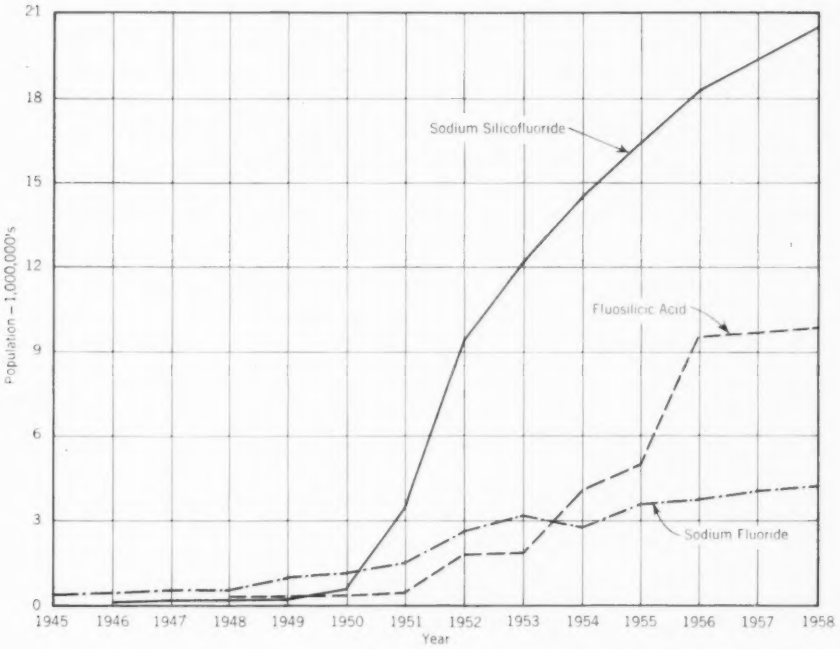

Fig. 3. Annual Cumulative United States Population Served Fluoridated Water, According to Chemical Used, 1945–1958

Only two communities use calcium fluoride; no ammonium fluosilicate installations have been instituted since 1954.

The foregoing report confirmed the opinions of a majority of the panel members who presented papers at the 1957 AWWA conference in Atlantic City, N.J.[5]

Acknowledgment

The task group is greatly indebted to Franz J. Maier, sanitary engineer director, USPHS, for providing the statistical data appearing in the foregoing tables and figures.

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Rate-Making Regulations and Financing in West Virginia

Myron R. Renick

A paper presented on Oct. 29, 1959, at the West Virginia Section Meeting, Parkersburg, W.Va., by Myron R. Renick, Chairman, West Virginia Public Service Com., Charleston, W.Va.

WITHIN the jurisdiction of the Public Service Commission of West Virginia, water utilities are divided into two distinct and separate classifications: (1) those owned and operated by political subdivisions of the state and (2) those privately owned. Most of those utilities operated by political subdivisions of the state are municipally owned and operated and usually serve customers within and adjacent to the municipality as well as customers within clearly defined public service districts created by the county courts. Such utilities operate tax-free, with the exception of certain federal excise taxes and a few specific federal payroll taxes, such as social security.

Both the publicly and privately owned utilities are dedicated to the public service. The obligation of rendering adequate service to customers rests with those charged with the responsibility for operation of the water system.

In order to render satisfactory service, water utilities must have sufficient gross income to pay their operating expenses and to provide sufficient reserve funds for the replacement of facilities through systematic application of fair and reasonable depreciation rates.

West Virginia Regulations

West Virginia, instead of allowing a fair rate of return (as is done for privately owned utilities), allows a municipally owned utility to charge rates broad enough to produce sufficient funds to pay reasonable operating expenses (including depreciation), to service debt capital, and to provide sufficient surplus for needed additions or replacements.

One of the major difficulties encountered by West Virginia in the regulation of municipally owned water systems has been the failure of the utilities to set aside a sufficient depreciation reserve to enable them to make replacements made necessary by the wearing out or obsolescence of equipment or facilities. It should be pointed out that under West Virginia law, funds generated by a municipal corporation's operation of utility services may not legally be expended for any purposes other than those directly related to the operation of the utility.

Accounting Records

In the matter of rate making, specific obligations fall by law directly upon the public service commission. The duty of determining the fairness and reasonableness of rates and charges for

services offered—in view of the investment in facilities, prevailing operating costs, proper allowances for depreciation, taxes, financing, and other pertinent factors, including the value of the service rendered—is the prime responsibility of the commission. Utilities are required to keep records, in account form, as prescribed by the commission. These records must cover buildings and equipment, operation costs, and financing, as set out in the uniform system of accounts for water utilities prescribed by the commission.

Only by keeping accurate accounting records are utilities able to be apprised of their financial condition at any given time and to supply the commission with required information. Such accounts provide a current standard against which the impact of changes in the economy can be measured.

Any utility has recourse to the commission. Its legal, engineering, and accounting facilities are available whenever:

1. Changes in rates and charges become necessary due to increased operating costs

2. Established rates and charges fail to provide sufficient revenue funds for a privately owned utility to pay necessary and reasonable operating expenses, provide for adequate depreciation reserves, pay applicable taxes, and provide a fair and reasonable return on investment

3. Established rates and charges fail to provide sufficient revenue funds for a publicly owned utility to cover reasonable operating expenses, provide reasonable reserves for depreciation and obsolescence, pay applicable taxes (usually social security taxes only), cover interest on outstanding bonds, retire bonds in accordance with governing ordinances, and provide a reasonable reserve for contingencies.

A utility may, through its management, file an application for authority to change its rates and charges for service, or a new tariff, to become effective at a specified date at least 30 days from the filing date. In either case, the utility must file, or be in a position to file, complete statements and schedules covering its facilities in the public service and their original cost, as well as balance sheets and operating statements.

Following receipt of an application or tariff, the usual procedure is for the commission to set the case for hearing. At that time, the utility and the general public are given an opportunity to present such evidence as they may have to substantiate or protest against the application.

If a tariff is filed to become effective on a stated date the commission usually suspends the tariff for the maximum period allowable under the law (120 days) and institutes a proceeding in which the utility becomes respondent to the commission's order to show cause or justification for its tariff. In such cases the same accounting and financial statements are required. The burden of proof rests with the utility asserting the need for revision of rates and charges.

The facilities of the commission's engineering and accounting departments are usually utilized to provide the commission with information as to the condition and adequacy of facilities, valuation and estimated life of property, and a verification of the financial accounts presented.

Although there are many routine duties involved in the rate-making

process, there usually are, at the same time, many unusual situations which must be considered by the commission in an attempt to determine what information is relevant to a hearing.

Rate-Making Procedure

There are at least four distinct steps in the rate-making procedure in West Virginia:

1. An application for authority to change rates and charges—and for a certificate of convenience and necessity, if the public utility is just starting operations—are presented to the public service commission.
2. A date is set for a hearing at which the applicant (or respondent) submits exhibits and gives testimony in support of the application or tariff. At the same time, protests, if any, are received.
3. Upon completion of the hearing, the case is referred to the accounting department for an examination of the books and records and a report of the audit is furnished to the commissioners.
4. The commission meets for the consideration of all of the evidence and for a final ruling.

In addition to the task assigned to the accounting department, the commission may—and does, with increasing frequency—call upon its engineering staff for studies and reports to be used in conjunction with those of the accounting department. Thus, there is a two-pronged approach to the problem of rate making. It is through the utilization of all available facts that the commission can best determine just what constitutes a fair decision in a given case.

Financing of Improvements

A privately owned public utility may obtain capital in one or more of several ways: (1) sale of common capital stock, (2) sale of preferred capital stock, (3) mortgage bonds, (4) notes, (5) internal financing from depreciation accruals, tax accruals, and from undistributed earnings.

Many factors are involved in the decision of what specific type of financing to use. Some of these are the effect of income and other tax regulations, policies of the federal government in supporting interest rates, and the demand for and availability of funds in the money market.

Other items which merit consideration are the financial condition of the utility, the history of its earnings, its dividend policy, the existing capital structure, and the possibility of growth.

Municipally owned utilities generally obtain funds for improvements from the sale of revenue or general obligation bonds, depreciation accruals, tax levies, and surplus. In view of the present and anticipated future condition of the money market, and the high prevailing discount rates, the time may well have arrived for municipally owned utilities to give serious consideration to the possibility of financing routine improvements and additions on a pay-as-you-go basis.

Electronic Computers in the Water Supply Field

Robert S. Gooch

A paper presented on Oct. 21, 1959, at the joint meeting of the Alabama-Mississippi and Southwest sections, New Orleans, La., by Robert S. Gooch, Associate, Freese, Nichols & Endress, Fort Worth, Tex.

SO much has been said and written about electronic computers in the past few years that just about everybody in the water supply field has at least a vague idea of what they are and what they are able to do. As more general ideas are formed about the speed and reliability of these machines, more and more men are putting them to use in water supply applications, and they are well satisfied with the results.

Usefulness in Water Industry

It is quite clear that computers are here to stay, and, of course, the fundamental question in the water utility man's mind is whether this fact really has much to do with his own job. This is not a particularly easy question for the average man to answer, because it is very difficult to know about computers before he has actually *done* something with one of them. He is confronted with a new type of practical mathematics; it boasts its own vocabulary, has its own peculiar thought processes, and involves a rather imposing array of electrical-mechanical devices. He must gain an elementary understanding of these before he can hope to decide what significance it may have in his work.

This situation is similar to that of a ninth-grade student when first confronted with algebra. He, too, is dealing with a new way to solve problems. Algebra is not at all like the mathematics he has been accustomed to, and it is the terrifying difference which makes it seem to be so hard to learn.

Advantages of Computers

Computers very obviously are of considerable significance to anyone whose work involves any sort of mathematical analysis. This automatically includes much of the management and operation of major water supply systems; certainly, it extends to almost all water works engineering. For men whose work falls in these categories, there really is not much choice as to whether or not to start using electronic computation. It is possible to do so much better work with the added mathematical power of a computer that it is simply not within reason to refuse to use them.

Virtually any significant mathematical problem can be solved faster, more reliably, and more economically by means of a computer, but the computer is neither more nor less than a tool. Its value, like that of any other tool, depends on its use.

Necessary Training

Most people, when they first confront the issue, are not quite sure they are capable of using a computer. Like the ninth grader with his algebra, they cannot help being a bit afraid that they have met their match. Actually, of course, there are many degrees of computer skill, just as there are many degrees of skill in algebra. But the author is convinced, after watching a number of men start using computers without benefit of special background or extraordinary knowledge, that anybody who can understand a mathematical problem well enough to solve it by conventional methods is capable of using a computer to solve the same problem.

Obviously, a beginner at high-speed computation is going to need some help. Fortunately, there are numerous commercial organizations whose principal stock in trade is skill with electronic computers. At the start, the beginner should rely upon such an organization to help him set up his problems. In this way he will get satisfactory results the first time and will pick up the background that is necessary if he is later to use the computer by himself.

Another very important source of help is the manufacturer of the computer. The manufacturers and their sales agencies are, as a rule, very eager to help people to become thoroughly familiar with their products. They will be glad to furnish manuals and some technical assistance to anyone who is trying to set up a problem for solution on one of their machines.

Most computer manufacturers offer special training courses. Anybody who is seriously setting out to use a high-speed computer should consider a training course well worth the time and expense. After all, there is much to be learned. The manufacturer's course will furnish reliable information in concentrated doses, so that it can be learned correctly and efficiently. There is a strong possibility that a week or two spent in classes will be amply rewarded by the avoidance of mistakes in actual application of the computer later on.

Above all, the important thing to keep in mind when one first begins to use a computer is that anybody with enough intelligence to understand a mathematical problem can find the assistance and knowledge necessary to use a computer for its solution.

Economy

Almost without exception, it is more economical to do mathematics with the aid of a computer than to do the same work by conventional methods. In some instances, when a specific problem is to be solved only once, the computer solution may be more expensive, but, even then, its other advantages should recommend it for consideration. Because of the speed and reliability of the computer, its work is unquestionably worth more than a manual solution, although, as a rule, the computer approach costs less. Another outstanding advantage of the computer is that the combination of speed and low cost allows an analysis to be completed with absolute thoroughness, whereas the older methods often required shortcuts in the interest of time or economy.

Large and Small Computers

One of the first questions which arises is whether to use a small or a large computer. As an almost infal-

lible rule, a problem should be worked out on the most powerful available machine that the scope of the problem will justify. Following this rule will save much time and trouble. It will also be more economical; a larger machine works enough faster than its less capable competitors to turn out the required results for less total cost.

By working with the larger machines, one is able to develop a better set of standards by which to judge the merits of lesser computers. When the time comes to select a computer for permanent installation in one's own offices—and that time will probably come sooner or later—experience with the broader capabilities of the large computers will help in deciding just which characteristics are essential and which are not. The simpler equipment does not offer all of the advantages of the more complex installations, and only by experience can one evaluate the importance of the functions that have been left out of the various smaller models.

Analog and Digital Types

There is a good deal of very active argument about the relative merits of analog and digital computers. In the author's opinion, this debate is more than a little irrelevant, because the two types are not truly comparable. It is most desirable to develop at least a conversational familiarity with both types, and to keep an open mind toward the use of either of them. Neither type has any monopoly on the solution of mathematical problems.

There are some water supply problems—for instance, distribution network analyses and problems involving hydraulic transients—which seem naturally to suggest analog solutions. On the other hand, the basic principles involved in the use of a digital machine are certainly closer to the common approach to problems and thus likely to be easier to understand.

For most organizations in the water supply field, what is needed is a very versatile computer that can be operated by someone with a minimum of specialized training. This probably means that most water supply men should start out by working with one or another of the digital machines. For many specific types of problems, however, an analog computer has been found to be superior. It should be remembered that there are computing-service firms with special analog equipment, ready and waiting to solve the problems for which it is best suited.

Trend Toward Computers

Because of their marked advantages, the author believes that electronic computers will eventually be used almost universally for mathematical analysis in the water supply industry and in all other industries. The widespread use of computers will mean that most water utilities and engineering firms of any significant size will sooner or later set up computer installations of their own. If this assumption is correct, then water supply men should orient their thinking first toward learning how to use computers and then toward deciding which machine to install in their own organizations. If, as seems to be true, the trend toward computers is inevitable, then the sooner water men start taking advantage of them the better.

Of course, the change will not take place overnight. Most utilities are still doing a good job with desk calculator methods and desk calculator ideas,

and it is neither desirable nor necessary to change things in a hurry. On the other hand, it is important to recognize and adopt methods that make it possible to do a better job in the future.

An important factor in the economics of computer use is knowing when to lease or purchase a computer of one's own. Two fundamental questions should be answered before any organization installs its own computer: (1) whether the machine under consideration can be kept busy enough to earn its keep, and (2) whether it can handle all of the problems that will need to be solved. The first question can be answered only gradually by finding out where the computer can be used to advantage and adapting older methods to include high-speed computation. The answer to the second question must be based on a fair degree of familiarity with the computer field. Together, the answers to these two fundamental questions will probably take several years of experience and inquiry. Only then will most organizations feel that they are ready to install and operate their own computers.

Conclusion

The commercial development of high-speed computers is a matter of profound importance to the water supply industry. The industry is hard pressed by population growth, increasing per capita consumption, stream pollution, explosive metropolitan expansion, and a host of other problems. To cope with these difficulties there is an urgent need for first-rate engineering, first-rate management, and first-rate water utility operation. Under the circumstances, it seems that the electronic computer has been made available to the industry at a time when it is most urgently needed. Water supply men should welcome this means for doing better work and be quick to take advantage of it.

Principles of Good Employee-Management Relationships

Panel Discussion

A panel discussion presented on Sep. 25, 1959, at the Michigan Section Meeting, Saginaw, Mich.

Selection and Supervision of Employees

Herbert L. Keinath

A paper presented by Herbert L. Keinath, City Mgr., Frankenmuth, Mich.

THE chief administrator or supervisor responsible for the hiring of personnel for municipal employment should be allowed as much freedom in hiring as possible. To this end, it is imperative that the responsibility for selecting or hiring employees be stated in an ordinance or resolution of the city council, so that outside and political influence on hiring can be held to an absolute minimum. Delegating the selection of employees to the person who is ultimately responsible for the employee's competence, morale, and performance is good policy, and will cause that person to determine carefully the qualifications and abilities of the applicant. Under a competent administration, a personnel program that allows for complete freedom of hiring will, in the long run, result in a first-rate municipal organization. In such an organization, each worker is proud of his employment and is stimulated to do his best. There is general job satisfaction because each person has the sense of belonging at the job he is doing. Nothing contributes more to the morale of employees individually and as a group than the knowledge that good work is rewarded by official recognition and that the dignity and importance of individual employees are recognized and appreciated by the community as a whole.

Employment Policies

Years ago, the author had the exasperating experience of supervising a group of employees who were on the public payroll because they were either too old or otherwise unable to hold another job. It was almost impossible to get satisfactory performance from such a group. The pay scale was low, the morale even lower, and the organization was referred to by the public as an "old-folks home." There is probably no community without a personnel program, be it good or bad. The selection of employees, particularly in the smaller communities, is often done by lay people on the council who have only a vague idea of what qualifications are desired and an even vaguer idea of what an employee is actually supposed to do when he is hired. As the salary and wage budget in most

municipalities accounts for a considerable portion of the total budget, it is imperative, in the interest of economy and efficiency in government, that a sound and effective personnel program be established. The success of such a program depends, to a large degree, on the freedom of a supervisor to select his personnel.

In more recent times, the author has had the opportunity to build a municipal organization with complete freedom of employee selection. The organization now has a youthful group of employees who are competent in their jobs, who are friendly, cheerful, and cooperative, and who have the potential for advancement, which they demonstrate by their initiative and good judgment. These employees have welcomed the opportunity to learn and are daily applying effectively what they have learned. They have a real interest not only in their jobs and in their own future, but also in the total program of the community.

Employee Needs

The task of building a first-class municipal organization does not end with freedom of employee selection. A sound personnel program will insure that each worker is effectively engaged, that only needed workers are employed, and that wage and salary rates are commensurate with the duties performed. The average employee wants: (1) a job he can do, one that is a challenge and leads to promotion; (2) a supervisor who knows his job and who will provide leadership and good supervision, but who will also recognize the employee's capabilities and shortcomings and will help him to do a better job; (3) the privilege of being informed of the organization's operating plans and problems and of participating in their solution; (4) the respect of associates and the public; (5) a fair rate of pay for work performed, with merit increases; (6) an opportunity for promotion and greater responsibility and increased pay when qualified; and (7) reasonable job security, based on satisfactory job performance.

In any organization the employees' morale is extremely important, and there are many things that the leader or supervisor can do to promote it. The supervisor can, for example, make certain that each employee understands the aims and goals of the organization and is permitted, as much as possible, to participate in its plans and policies. The employee must be encouraged to realize the advantages of belonging to, and working with, the group. He must be given only his share of routine or disagreeable work; the boss or supervisor must be prepared to do his own share. When discipline is required, the abuse of authority and threat of punishment is to be avoided, and an employee should never be disciplined in front of the group. Whenever an employee does his job well, he should be praised. The administrator must not criticize too severely those errors that an employee makes in good faith.

—Winning Employee Confidence—George E. Matthews—

A paper presented by George E. Matthews, Supt., Maint. & Installation, Water, Sewer & Meter Dept., Muskegon, Mich.

Two prime factors must be considered in a discussion of good employee-management relationships:

1. A person wants to feel that he is important and respected.
2. A person wants security for himself and for his family.

These factors should be considered by municipalities especially, because of the relatively low wages paid to municipal employees. Wages, therefore, must be augmented by good employee relations and job security.

Exchange of Ideas

An employee must be able to believe that regardless of his job, his work is important to the organization. His ideas must be respected. All successful organizations were developed because new ideas were utilized. Therefore, the avenues of communication between employer and employee are very important. Management can develop avenues of communication by arranging regular and frequent meetings at which ideas can be exchanged. Such meetings should be informal, so that the employee feels at ease. Although the frequency of these meetings is important, it is often better to have fewer but more active ones.

A list should be made of the suggestions offered by employees, and the merits of the suggestions discussed. If an idea is used, the employee who thought of it should be informed of the actions taken and the results. In this way, he will not only feel important and respected, but will also be more willing to present other ideas.

During these discussions, the employee should be made aware of the organization's problems and future plans, which should be explained in terms that he can understand. Such an awareness will stimulate thinking and promote new ideas. Furthermore, when workers have a thorough understanding of their jobs, they work more efficiently.

Another way in which management can win the confidence of employees is to be honest and fair by treating all personnel equally. A supervisor can take his staff into his confidence without causing the loss of respect for his position. Personal day-to-day contact is very important; a smile and a wave of the hand can make an employee feel that he is important and respected.

An education program may be helpful for informing employees of new tools and methods that help to get the job done more efficiently. Such a program might utilize such visual aids as charts, slides, and movies. Employees themselves could be urged to demonstrate new tools, or, with complex, new equipment, specially trained instructors might be more desirable. It is always important to remember that management cannot expect an improperly instructed employee to do the best job.

Morale and Welfare

When applying methods to build the morale of an organization, management might start by painting the plant and giving buildings and surroundings a new look. Neat and orderly arrangements in the shop are a constant re-

minder to workers that tools and equipment should be cared for. To raise morale further, a well organized safety program should be put into effect. Such a program makes an employee aware that management is interested in his welfare.

With regard to job security, benefits in themselves provide no guarantee, for an employee is frequently as secure in his job as he can be. This fact must be considered when hiring personnel. If an individual is not qualified mentally or physically, he will not feel secure in his job because he will be conscious of his own limitations.

The question of promotions must be kept in mind when people are hired. Each employee's qualifications must be considered, but regardless of his job, his accomplishments must always be recognized, if not with a fatter pay envelope, then at least with a pat on the back and sincere thanks.

Importance of the Individual in Small Utilities

Carl R. Nelson

A paper presented by Carl R. Nelson, Supt., Water Dept., Adrian, Mich.

Good labor relations narrow down to good human relations, and one cannot have good human relations without recognizing and believing in the importance of the individual. This is never more true than when applied to a small operation involving only a few employees.

Many excellent books and articles have been written about labor relations. One can read about recommended personnel records, grievance procedures, job rating, promotions, and training programs. These articles are informative, but they are generally geared to the large organization.

In Michigan, there are approximately 750 municipally owned water utilities. Of these, 700, or about 93 per cent, serve communities of 20,000 people or less. In these utilities the number of employees ranges from two or three to probably not more than twenty. In most instances, these employees are not members of a union. Formal grievance procedures, training programs, and job rating or classification must be simplified and made flexible to be adaptable to the small utility.

In the average annual budget of a utility, the highest percentage of the operating expense will be allocated to salaries and wages. City charters and city councils are explicit and restrictive about the purchase of materials and equipment. Yet, thought is seldom given to the development of the greatest resource in any organization—human potential. It may seem paradoxical to question the value of formal employer-employee programs, about which so much is written, and, at the same time, to stress the importance of developing human resources. How can the manager of a small water utility resolve this problem?

Simply stated, the best approach to labor relations in the small utility is through good human relations. Basically, this calls for recognition of the importance of each individual. In the small organization, a close relationship develops between the boss and his workers. This personal contact can be

a problem in itself, but it also provides an ideal situation in which to develop and capitalize on the human relations aspect of labor relations. To do this, one must constantly be aware that the human resource under his direction is the greatest potential in the organization. People usually can do more than they think they can, but usually do less than they think they do. Whether one can encourage 20 per cent or 80 per cent effectiveness from employees is a consideration far more important that the best purchasing procedures ever devised. How can an employer encourage maximum effectiveness from his employees?

1. Respect the dignity of the individual.
2. Encourage the development of each man.
3. Develop *esprit de corps*.

Dignity of the Individual

As mentioned before, respect for the dignity of the individual is of basic importance to good labor relations. This by no means suggests a Pollyanna-like attitude, but a genuine belief in the philosophy behind it. If an employer believes in human dignity, he will automatically observe the simple courtesies to which his fellow workers are entitled. When he arrives at work, he greets his workers by name; he inquires about their families; but he never becomes involved in domestic disputes. He treats his workers with respect. These are seemingly small matters, yet they help bolster morale and develop a team relationship.

Development of the Individual

The second point, to encourage the development of each individual, can be a problem in a small water utility, except with regard to plant operators. Operators should be encouraged to take short courses and sit for examinations. After receiving a license, they can look beyond the local organization for opportunities. For the rest of the organization, however, there is limited opportunity for advancement. Individual development must be related to the employee's present job. First, he should be helped to become proud of his particular part in providing his community with the most vital of all human necessities—water. He should be encouraged to think and to make suggestions. Many of his suggestions will have to be tactfully rejected, but when they are worthy, they should be adequately acknowledged. A thinking employee is one of the greatest assets in any organization. There is always a better way to do a job, and the man at the grass roots of an operation is in a position to observe details about which his employer knows little.

Esprit de Corps

Group morale and enthusiasm are directly related to a worker's pride in being a part of the water utility. Even a small city cannot exist without a water system; furthermore, no city can grow larger than its water supply. The vital importance of the water utility in a community is all too often overlooked and taken for granted, although it is the lifeblood of the community, and every part of its operation is significant. The utility manager's attitude to, and belief in the importance of, the water utility will have more effect in enhancing the respect for his organization than anything else he can do. A worker does his best when he is proud of his job.

Relationships With Nonunion Employees

—*W. F. Marklund*—

A paper presented by W. F. Marklund, Distr. Supervisor, Div. of Water Supply, Flint, Mich.

It is often said that top management gets the kind of labor relations it deserves. When employees feel that they are being treated fairly and that working conditions, wages, and fringe benefits are satisfactory, they often realize that an outside organization can be of little benefit to them. Also, if there is good communication between management and employees, if grievances are handled fairly and the organization has community prestige, labor's need for outside assistance in obtaining its rights is greatly reduced.

Many factors influence labor's decision about joining a union. In a recently organized plant, where management thought that things were running smoothly, one of the employees said:

> It isn't the big things that cause all the gripes, it's the little things and the company's attitude. Some people voted to join the union to get back at management. The folks here didn't want a union, but they feel that management doesn't care about them; they feel insecure. There are no explanations about jobs or pay rates, and employees have no idea about how they fit into the company's plans. People are promoted or moved from job to job with no regard to seniority, and often the same job will have several pay rates.

A few years ago, the Institute of Labor and Industrial Relations of the University of Illinois made a study of the relationship between the worker's attitude toward the company and the company's attitude toward the union. Although this study dealt with eight companies that were unionized, the findings are probably just as true for an organization dealing with nonunion employees. Six of the companies studied were paired off according to type of work; there were two construction companies, two garment manufacturers, and two trucking companies. The union agents were the same for each pair of organizations, and the companies were in the same city. Therefore, the difference between companies was largely in the management. In all instances where management was hostile to the union or had a poor record of labor relations, the worker's attitude toward the company was poor; where management and the union were agreeable and cooperative, the worker's attitude toward the company was much the same. In one instance, a company executive felt that the union employees were not good workers, that the business agent was unreasonable, unpredictable, and dictatorial, and that it was the union's influence that swayed the employee vote. But it was made clear from interviews of the workers by the study group that it was the company's actions that were important to the workers, not what the union told them. One attitude of management that was particularly important concerned the manner in which collective bargaining was conducted. To some executives, bargaining was a normal part of business, and every effort was made to have it go smoothly. Others saw it as a necessary evil and tried to tie it down with restraints.

Responsibilities of Management

Management's ability to deal with employees is becoming more important

than its know-how of the job or business. Some authorities believe that management training should be 90 per cent employee relations and 10 per cent job know-how. This ratio seems out of line for municipal work, especially when the supervisor must be a jack of all trades and the organization deals in services to the public. There are many things, however, that can be done to bring about good labor relations without the need for a third party, either as a union for the workers or as a labor relations council for the supervisors.

If management would imagine itself in the position of the worker and look at things as workers do, it would realize that many problems are the result of individual attitudes and ways of doing things. Employees should be treated as important individuals. When it is necessary to reprimand an employee, it should be done in private, but credit should be given before the group. Employees should be informed in advance about changes that will affect them. The best use should be made of each person's abilities. Successful communication between employees and supervisors is one of the most important phases of good labor relations. The tone of a supervisor's voice may prevent an employee from listening to the message; words must be chosen carefully to convey the same idea to all employees. Favoritism should be avoided. Although most supervisors probably trust some employees more than others, work should be assigned on a fair and equal basis. Overtime should be distributed equitably and under a predetermined plan. City or company policies concerning employees should be administered the same way to all employees, and discipline should be administered under an established method. Supervisors should have a policy with regard to seniority, as it affects layoff, recall, promotion, or transfer. Working conditions are probably neglected in many municipal departments, either because of a lack of funds or because buildings are old and inadequate. A few gallons of paint and some good old-fashioned scrubbing will work wonders in many instances. One water department improved its working conditions by converting an old, unused coal bin into a lunch room and locker room, and by building two showers in the boiler room.

Wages, as one of the factors in management-labor problems, have not been discussed because utility managers usually can do little about them. There is, however, something that will curtail complaints: job classification and evaluation. If employees are under civil service, undoubtedly this matter is dealt with. Jobs and duties, however, are constantly changing, and the supervisor should insure that additions to, and subtractions from, duties are shown in the job specifications, and that the pay scale is adjusted accordingly. If employee qualifications are not controlled by civil service, even a small organization can set up a list of job duties, skills, experience, and educational requirements, classifying similar jobs in similar pay categories and keeping the work within these limits as much as possible.

Finally, supervisors must be reminded that each person is an individual with varied and complex feelings that cannot be evaluated like a piece of equipment. If supervisors use good judgment and treat their personnel as supervisors themselves would like to be treated, a firm basis for good labor relations will have been established.

Techniques and Economics of Calcining Softening Sludges

Joint Discussion

A joint discussion presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif.

Calcination Techniques—*William B. Crow*

A paper presented by William B. Crow, Cons. Engr., Black & Assocs., Inc., Gainesville, Fla.

RECALCINATION of softening plant sludge is a process in which the sludge, concentrated in a centrifuge to at least 60 per cent solids, is burned at 2,000°F, the calcium carbonate and magnesium hydroxide present being converted to oxides.

The greater portion of the carbonate hardness present in natural waters is normally due to calcium bicarbonate, which is precipitated by either hydrated lime or quicklime. From the simple stoichiometric ratio obtained from the reaction:

$$CaO + Ca(HCO_3)_2 \rightarrow 2CaCO_3 + H_2O$$

1 lb of pure calcium oxide should theoretically produce 3.57 lb of dry calcium carbonate sludge. In actual practice, the theoretical yield is never obtained, owing to the presence of impurities in the lime and to the varying amounts of magnesium which are removed from the water. Usually, approximately 2.6 lb of calcium carbonate is obtained from each pound of quicklime used in treatment, from which 1.24 lb of lime is recovered with a nominal recovery efficiency of 85 per cent, allowing for the production of 20–25 per cent excess lime. The difference between the theoretical conversion and actual recovery is attributable to mechanical losses in the dewatering and dust recovery equipment. The calcium carbonate is decomposed by heat, yielding calcium oxide and carbon dioxide as follows:

$$CaCO_3 + \Delta \rightarrow CaO + CO_2\uparrow$$

The carbon dioxide released is often used in the water treatment process.

Recalcination of calcium carbonate sludges has been practiced for many years in the pulp and paper industry. The economic success of the kraft paper process requires this conversion in the recausticizing operation. Until recently, however, this practice has not been widely applied in the water supply field, mainly because of the small tonnages involved, and because the magnesium content of the sludge must be minimized.

Basic work by Hoover,[1] Aultman,[2] Nelson,[3] Pedersen,[4] Black,[5] and Sheen and Lammers[6] has contributed substantially to the adaption of recalcination to the water supply industry. The most recent contribution has been

by Eidsness [7] in the carbonation of water-softening sludge for magnesium removal.

Economics of Calcination

The principal factors affecting the economics of recalcination are:

1. Amount of lime required for treatment
2. Freight cost of delivering lime
3. Sludge disposal expense
4. Cost of carbon dioxide for treatment
5. Prevailing cost of fuel and power.

Studies have indicated that recalcining plants with capacities as low as 6 tons per day may be feasible where sludge disposal is a critical and expensive problem. Production costs of various installations range from $7.50 to $28 per ton of capacity.

Existing Installations

During the past year, four major domestic water treatment installations have practiced recalcination of softening sludge. These installations are at: Miami, Fla.; Dayton, Ohio; Lansing, Mich.; and Marshalltown, Iowa. In addition, Salina, Kan., and Gainesville, Fla., have recently constructed calcining plants; however, complete operating data for a period of a year are not yet available. Another recalcining plant is currently under construction for San Diego, Calif.

The three principal systems for recalcination of softening sludge are: the rotary kiln, pellet-seeding calciner, and the flash calciner. The existing recalcining plants are classified as to calcining method and capacity in Table 1.

The rotary-kiln and the pellet-seeding plants both yield a product having an available-CaO content of approximately 93 per cent at a fuel rate of 8,500,000–12,000,000 Btu per ton, and each produces a pelletized or nodulized quicklime, whereas the flash calciner yields powdered calcium oxide.

Rotary-Kiln Process

A flow diagram of the typical rotary-kiln calcining plant is shown in Fig. 1. The lime sludge is first dewatered by centrifuging and is then fed to the kiln as filter cake consisting of 65 per cent solids and 35 per cent moisture. The chain section of the kiln acts as a heat recovery device and exposes the cake to the kiln gas. The kiln shell has a refractory lining, rotates at approximately 1 rpm, and is inclined to a slope of $\frac{1}{2}$ in./ft to facilitate the travel of the dried sludge toward the firing end. Retention time in the kiln is usually $1\frac{1}{2}$ hr and the sludge is nodulized and converted into quicklime in the calcining zone before it discharges into an integral tube cooler. The cooler tubes are mounted on the periphery of the kiln shell and contain flights to move the product uphill and discharge it into a screw conveyor. The lime is then transferred to storage by a bucket elevator.

Air is supplied to the gas or oil burner for flame control. Air also en-

TABLE 1

Existing Recalcination Plants

Municipality	System Type	Capacity *ton/day*
Dayton, Ohio	rotary kiln	150
Miami, Fla.	rotary kiln	80
Lansing, Mich.	pellet seeding	30
Marshalltown, Iowa	flash	10
Salina, Kan.	flash	25
Gainesville, Fla.	pellet seeding	6
San Diego, Calif.*	rotary kiln	25

* Under construction.

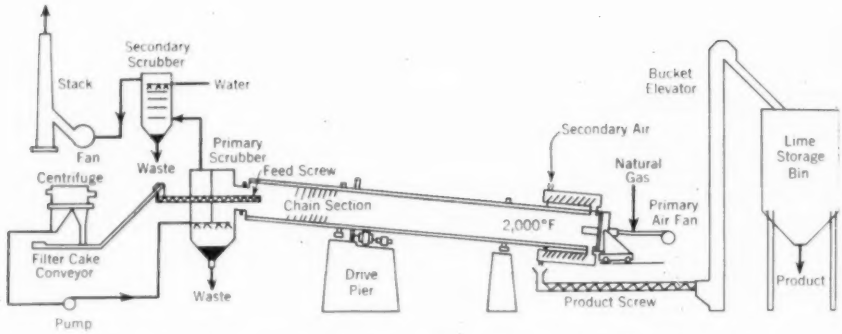

Fig. 1. Schematic Diagram of Rotary-Kiln Calcination Process

Dewatered lime sludge is fed to the kiln as filter cake. After firing, the product is discharged into a screw conveyor and transferred to storage by the bucket elevator.

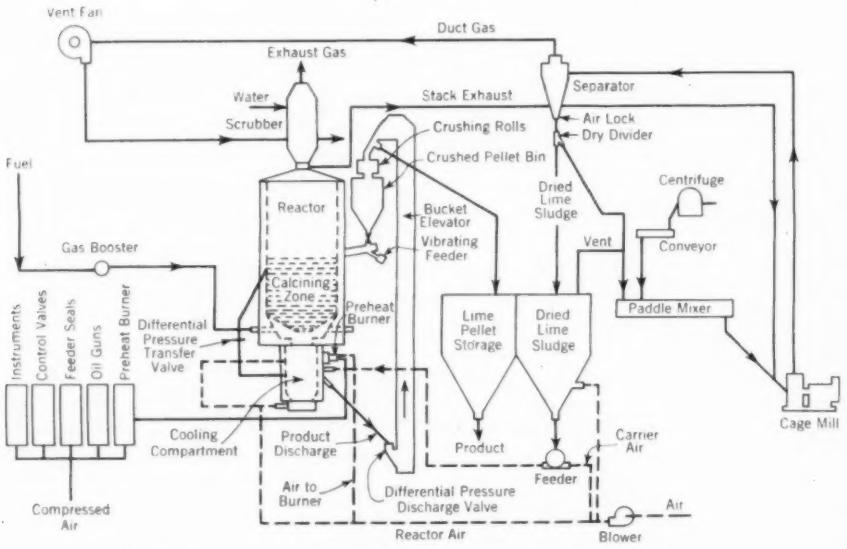

Fig. 2. Schematic Diagram of Pellet-Seeding Calcination Process

Filter cake is blended with dried sludge in a paddle mixer and discharged into the cage mill and flash drying system. The dried sludge is deposited in a storage bin for feeding to the reactor, which is supplied with air by a centrifugal blower. Lime pellets are added to act as nuclei for the deposition of the dried sludge. Soda ash is added to control pellet growth. After cooling, the finished product is transferred to storage, a small quantity being diverted to the crushing rolls and kept for reseeding.

ters the tube coolers through the product discharge parts. The temperature within the kiln at the calcining zone is thus maintained at approximately 2,000°F, and the kiln exhaust gas at the feed end housing is 400°F. The scrubber removes traces of dust before releasing the exhaust gas to the atmosphere.

Pellet-Seeding Calciner

The sludge is dewatered for calcining in the same way in the pellet-seeding process as in the rotary kiln; after that point, however, the process is quite different. A flow diagram of the process is shown in Fig. 2.

The filter cake is blended with dried sludge in a paddle mixer and discharged into the cage mill and flash drying system. Drying is accomplished by the use of the reactor exhaust gas. A centrifugal cyclone separates the dried sludge from the air stream and deposits it in a storage bin for feeding to the reactor. Air is supplied to the reactor by a centrifugal blower at velocities sufficient to maintain a fluidizing bed within the reactor. Crushed-lime pellets are added to act as seeds on which the dried sludge is deposited and calcined. A small quantity of soda ash is added to regulate pellet growth. The calcined pellets are drawn through a differential-pressure transfer device and enter the cooling compartment, where the product is cooled and the reactor air supply is heated. The finished product is transferred by a bucket elevator to storage, a small quantity being diverted to the crushing rolls and a pellet bin for reseed purposes. The exhaust gas is induced from the separator through a scrubber before release to atmosphere.

Gainesville Plant

Gainesville operates a 15-mgd softening plant requiring a maximum of 6 tons of lime daily. Recalcination was first considered in 1954, after critical sludge disposal problems were encountered. This situation was temporarily resolved by discharge of the sludge through the sewage treatment plant. This was successful except for the difficulty experienced in drying the combined sludges. The undried sludge was then hauled by tank trucks to lands available as disposal areas.

Quicklime delivered to the plant site costs approximately $20 per ton, including unloading costs. This cost, together with sludge disposal expense, amounted to approximately $43 per ton of lime used in treatment.

In 1955, Gainesville purchased the Lansing, Mich., pellet-seeding pilot plant. The equipment was modified to provide for a production installation with a capacity of 6 tons per day. The facilities were placed in full-scale operation in the fall of 1958. A study of the preliminary operating data revealed a production cost of slightly over $27 per ton. An experienced record of 6 months indicates that a high quality of quicklime in pellet form is produced by operation of the lime recalcination plant. Although the production cost was $27 per ton, a substantial reduction in overall costs was made by the elimination of the sludge disposal problem. Further reduction in operating costs is anticipated when the plant converts to natural gas and when some personnel, necessary during development stages, are eliminated.

Conclusion

Recalcination of water-softening sludges is no longer in the experi-

mental and developmental stage; it is a proved process available to the water industry. Most of the problems inherent in early lime recovery operations have been eliminated by improved technique and new equipment now available.

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Miami Lime Recovery Plant—*Claude F. Wertz*

A paper presented by Claude F. Wertz, Director, Dept. of Water & Sewers, Miami, Fla.

In 1938, in a discussion of a paper by W. W. Aultman on reuse of lime in softening,[1] Charles P. Hoover of Columbus, Ohio, called attention to the mud problem and high magnesium problem in many water supplies, and added that Miami, Fla., with the largest softening plant in the country using well water, had the best chance to accomplish reclamation of lime at a reasonable cost. Early in 1938, Aultman had made his classic tests on the recalcining of lime at Boulder City, Nev., for the Metropolitan Water District of Southern California.

A. P. Black, of the University of Florida in Gainesville, was first employed by Miami in 1939 as a consultant on water-softening and treatment problems. After the Miami Water and Sewer Board started to function in June 1941, Black brought the matter of recalcining carbonate sludge to its attention. His first offield report and recommendation were made on Jun. 3, 1943. As at every lime softening plant, the problem of sludge disposal was becoming more acute each year; huge banks of sludge surrounded the Hialeah Plant, and a new 20-acre lagoon ½ mi away was slowly filling up.

Later in 1943, proposals were received from several consulting engineers, and early in 1944 the first report was obtained, setting forth probable construction cost, operating cost, and savings, and confirming Black's contention that recalcination would be a profitable venture. In June 1944, after submission of a more comprehensive report, in which the estimated construction costs were set at approximately $350,000, the board agreed to proceed with the installation of a plant. No action was taken on the matter through spring of 1945, however, and during the interim a private investor submitted a proposal to construct a lime plant near Miami and supply the needs of the department. This investor was primarily interested in the

carbon dioxide contained in the stack gas, which would be used to make dry ice. Meanwhile, the department was having difficulty in obtaining enough lime from its regular suppliers, and it was necessary on more than one occasion to ask the War Production Board Materials Section in Washington for help in obtaining additional carloads.

On Aug. 9, 1945, the board voted to reemploy the consultant firm to prepare plans and specifications for a recalcination plant. Bids on equipment and materials were received in 1946, including the major items, such as the kiln, centrifugal filter, pneumatic conveying equipment, and tower scrubber. Delivery of most of this equipment was made during the spring of 1947. In April 1947, bids were received on twelve additional items of equipment, as well as for the general construction and equipment installation.

Construction of Plant

Construction started in the early fall of 1947. It was delayed for 3 months by the October 1947 hurricane and flood, and it was completed by December 1948. The final cost was $792,521.

In 1947, construction had started to increase the capacity of the Hialeah Softening and Treatment Plant from 40 to 60 mgd. Lime was being used at the rate of about 1,800 lb/mil gal. The sludge lagoon already contained several hundred thousand cubic yards of material. The lime plant was designed for a capacity of 80 tons of quicklime per day, it being anticipated that the 60-mgd plant would not provide enough sludge for this total capacity, but that additional calcium carbonate would be trucked to the wash mill in the lime plant from the lagoon.

Thickening of Sludge

Calcium carbonate sludge from three clarifiers is pumped to two 32-ft diameter, 15-ft deep concrete thickener tanks equipped with thickener mechanisms having variable speed control. Additional makeup sludge may be recovered, when needed, from a 20-acre sludge lagoon by means of a scraper hoist and trucked 1¼ mi to the plant, where a wash mill reduces it to the liquid state. This liquid sludge is also pumped to the thickeners and mixed with the new plant sludge.

The thickened slurry, containing 20–30 per cent solids, is pumped by two sand pumps to an adjustable spiral scoop slurry feeder located on the top floor of the feed building. This feeder has a capacity of 10,000 gph and is driven by a four-speed motor, synchronized with the four-speed kiln motor. These motors are remotely controlled by pushbuttons at the control panel in the discharge building. Excess slurry over kiln feed requirements is returned by gravity to the thickeners.

Dewatering of Sludge

The slurry flows by gravity from the feeder to two dewatering centrifuges (40×60 in.) driven by 60-hp motors. The plant originally had but one centrifuge with a guaranteed capacity of 75 tons per day, dry weight, of calcium carbonate filter cake, containing about 35 per cent moisture. This produced but 42 tons of finished lime per day. In capacity tests the plant delivered 90 tons of lime, however, which represents a rate through the centrifuge of approximately 160 tons, dry weight, of sludge per day. This cake contained 66.8 per cent solids

TABLE 1

*Operating Costs at Lime Recovery Plant, 1950–58**

Item	Amount—$								
	1950	1951	1952	1953	1954	1955	1956	1957	1958
Supervision	2,413	3,499	3,372	2,495	2,766	3,591	6,935	5,455	5,810
Labor	40,338	40,802	44,574	47,954	50,099	51,314	45,124	51,194	55,890
Power	9,928	11,172	11,276	12,067	11,516	9,999	12,593	14,806	14,925
Fuel oil	46,549	51,538	62,980	56,887	62,203	64,706	79,346	90,327	88,443
Supplies & expenses	8,119	3,637	2,798	2,950	2,850	1,978	1,436	2,150	1,623
Maintenance	8,505	9,036	15,826	13,557	17,765	13,495	17,559	23,608	15,779
Operating cost	115,852	119,684	140,826	135,910	147,199	145,083	162,993	187,540	182,470
Outside lime sales	21,467	22,629	28,644	28,859	26,302	27,678	16,012		
Net operating cost	94,385	97,055	112,182	107,051	120,897	117,405	146,981	187,540	182,470

* Fiscal years ending Jun. 30.

and the filtrate, or waste water, contained 4.7 per cent solids. The second centrifuge was installed in 1954 as a spare.

Filter cake drops into a ribbon screw conveyor which delivers it through a plenum box into the feed end of the kiln. Waste water flows by gravity to the sludge lagoon.

Rotary Kiln

The rotary kiln is a four-support kiln of all-welded design, 7.5 ft inside diameter and 230 ft long, with an integral multicylinder cooler.* The kiln is driven through a reducing gear by a four-speed motor which can impart to the kiln selective speeds of 1.09, 0.85, 0.57, or 0.43 rpm. Normally the kiln is operated at 1.09 rpm. An auxiliary gasoline engine drive was originally provided for emergencies. In the past year a 25-kva, gasoline engine–driven generator has been installed for emergency use and for operation of the screw conveyor and bucket elevator, which delivers the finished product to storage.

The feed end of the kiln contains a 37-ft long heat-recuperating chain section which weighs approximately 11,000 lb. This chain section promotes an efficient exchange of heat be-

* UNAX; manufactured by F. L. Smidth & Co., New York.

TABLE 2

*Lime Production at Recovery Plant, 1950–58**

Use	Production—*tons*								
	1950	1951	1952	1953	1954	1955	1956	1957	1958
Use at Hialeah and Orr Plants	14,303	14,953	16,305	17,157	17,037	18,816	20,602	22,085	22,574
Sold outside	2,160	2,159	2,728	2,748	2,510	2,636	1,525		
Added to storage	30†	155	50	200	900	727	496	1,198	1,636
Total	16,433	17,267	19,083	20,105	20,447	22,179	22,623	23,283	24,210

* Fiscal years ending Jun. 30.
† Drawn from storage.

tween the hot exhaust gases and the incoming sludge. The effect of the heat-recuperating chain system is reflected in the low fuel consumption—approximately 55 gal of fuel oil per ton of lime produced.

The cooler consists of eight cylinders, equally spaced, around the outlet of the kiln. Each cylinder contains spiral conveying flights of heat-resistant cast iron. As the burned lime drops into these coolers and moves towards the collecting hopper, it is cooled from 2,100°F to approximately 600°F by the secondary combustion air. This effects another exchange of heat, which also helps improve the overall efficiency of the operation. From the collecting hopper, the lime drops into a screw conveyor which discharges to the boot of a bucket elevator. This elevator carries the material to a 460-ton steel storage silo, 25 ft in diameter and 46 ft high.

The kiln is oil fired by a mechanical, high-pressure, oil-atomizing system using Bunker C oil. The oil is preheated to approximately 200°F and is delivered to the nozzle under a pressure of 240–260 psi. The oil is preheated by a 15-hp steam boiler, which uses approximately 3 gal of fuel oil per ton of lime produced. A standby electric heater is also provided. A 100,000-gal steel oil storage tank is located immediately adjacent to the discharge building.

Primary combustion air, which is drawn from the top of the kiln and shield, is provided by an air blower rated at 2,300 cfm of 200°F air. Secondary air is drawn through the cooler cylinders. Temperatures in the firing zone of the kiln are maintained at 2,100°–2,200°F.

Draft control is provided by a 30-in. butterfly damper in the exit duct beyond the tower scrubber and ahead of the induced-draft fan. This fan had an original capacity of 12,500 cfm of moisture-laden gases at 90°–100°F, but its capacity has been increased to approximately 14,000 cfm by a change in the V-belt pulleys. The degree of opening of this damper is determined by the percentage of oxygen remaining in the exhaust gases. It has been found that a residual of 2 per cent oxygen in these gases results in maximum oil efficiency without any danger of producing noxious stack fumes.

TABLE 3

Cost of Lime Used at Miami Water-Softening Plants, 1949–58

Fiscal Year*	Cost of Lime Used $/ton
1950	6.60
1951	6.49
1952	6.88
1953	6.24
1954	7.10
1955	6.24
1956	7.13
1957	8.49
1958	8.08

* Ending Jun. 30.

Therefore, this point is carefully watched and damper control is all-important.

Stack Gas Scrubber

Because the softening plant is located less than ¼ mi from the business area of Hialeah and is surrounded by residential areas, it was necessary to eliminate all possibility of dust nuisance. A water-scrubbing tower, with a humidifier, is installed between the kiln and the induced-draft fan; its rated capacity for cleaning and cooling is 20,000 cfm. Gases are first passed through two atomizer sprays in the humidifier section before moving vertically upward in the 50-ft tower sec-

tion through four water sprays spaced about 10 ft apart. Approximately 350 gpm of water is used; all dust is effectively removed and temperature of the gases is reduced from 400°F to about 100°F.

Carbon Dioxide Reuse

Two compressors, each with a capacity of 570 cfm of free gas at 100°F against a gage pressure of 8 psi, deliver a portion of the stack gases, which contain approximately 25 per cent carbon dioxide, to the recarbonating basin of the softening plant. This effects a saving in cost of fuel oil burned to provide carbon dioxide gas for the water treatment process.

Waste water from the tower scrubber, from the sludge thickeners, and from other sources discharges to a sump, from which two 600-gpm sump pumps return it to the inlet end of the mixing basins of the softening plant.

Central Controls

A central control panel in the discharge building affords complete control for all equipment. It includes a recording pyrometer; percentage carbon dioxide and oxygen recorders, an oil pressure recorder, a flow and temperature meter, an air-operated combustion control unit, a draft gage, and various alarms. An intercommunication system is provided between the discharge building, the feed building, and the chief operator's room at the treatment plant.

Lime Transport and Storage

A pneumatic conveyor, rated at 10 tons/hr, moves the lime from the storage silo to the 100-ton bins in the chemical house—600 ft away—and to an 80-ton auxiliary silo used for loading trucks and freight cars; an exhauster in the basement of the chemical house and an auxiliary blower in the pit beneath the main storage silo furnish the high-velocity air for conveying the lime; a filter receiver is mounted on the roof of the chemical house; a reversible screw conveyor is used to deliver lime from the filter receiver to the lime storage bins above the gravimetric feeders in the chemical house. The pneumatic conveyor system is also used to deliver sodium silicofluoride from the treatment plant

TABLE 4

*Comparison of Costs of Purchasing Lime With the Costs of Lime Recovery, 1951–58**

Item	1951	1952	1953	1954	1955	1956	1957	1958
	Amount—$							
Cost of lime if purchased	299,060	326,100	343,140	340,740	395,136	453,244	485,870	487,598
Net recovery plant expenses†	97,055	112,182	107,051	120,897	117,405	146,981	187,540	182,470
Gross saving	202,005	213,918	236,089	219,843	277,731	306,263	298,330	305,128
Interest and depreciation	28,900	30,254	30,950	32,750	34,150	34,000	35,800	36,800
Profit on investment	173,105	183,664	205,139	187,093	243,581	272,263	262,530	268,328
Cumulative investment in plant	798,778	817,672	818,654	818,833	847,069	852,316	852,316	856,497

* Fiscal years ending Jun. 30.
† Exclusive of interest and depreciation.

warehouse to a 5-ton steel storage bin in the chemical house.

Operating Statistics

Tables 1–4 give the production costs, amount of lime produced, cost per ton of lime used in the department's plants and the indicated profit return on the investment. A review of these figures shows that the recalcining of water-softening sludge has been a very profitable venture. During the full 9 years from Jul. 1, 1949, to Jun. 30, 1958, the total profit return, or saving, amounted to $1,953,027. The figures in Table 4 show that the plant paid for itself in approximately 5 years.

The estimated interest-and-depreciation expense in Table 4 is admittedly light but it represents the average interest rate of 2.80 per cent on all outstanding bonds as of June 1958 and 1.5 per cent for depreciation, a percentage actually set aside in a depreciation reserve fund on the total value of the department's utility plant in service, amounting to $36,833,946 on Jun. 30, 1958. The total utility plant includes such items as transmission mains, distribution mains, and services valued at $22,647,203, all of which have a very long service life.

During the first 7 years of operation, excess lime was sold to Fort Lauderdale at $10.50 per ton. After adding their costs for trucking and handling, they still saved considerable money and Miami made a profit. An attempt was made to ship bulk lime by freight car as far as Tampa and Daytona Beach, but the water plants did not have proper equipment to transfer the relatively fine and dusty material from freight cars to a storage bin.

There are no weighing scales of any kind at the lime plant. A 1-cu ft steel box is filled from the discharge screw once each hour, and the time of filling and weight are recorded. The daily output is calculated from these hourly readings. Inaccuracies are covered by the amount added to storage (Table 2). Actual usage in the two softening plants is recorded by the weight totalizers on the lime feeders.

Maintenance costs (Table 1) remain fairly constant from year to year, averaging approximately $16,500 per year for the last 7 years. This is made possible by an excellent system of preventive maintenance. The operating force has been trained to do practically all of the maintenance work, including relining of the kiln. Twice each year the entire plant is shut down for a period of 7–10 days, during which time all machinery is inspected and the kiln lining is thoroughly gone over. All loose bricks are calked with chrome ore; consequently, the largest section ever relined completely was a 32-ft section in the firing end. In checking on the extra-high maintenance cost for the 1956–57 fiscal year ($23,608), it was found that a carload of fire brick costing $3,170 was charged to maintenance upon delivery instead of into the stores account, where it belonged. Additional above-normal costs included the resurfacing of two of the large roller supports (at a cost of $1,400) and painting of the structures.

The Alexander Orr Jr. Water Treatment Plant, dedicated in April 1954, is located approximately 13 mi south of the Hialeah plant. With an ultimate capacity of 100 mgd, 750 tons of lime storage bin capacity has been provided. It was originally intended to move lime by freight cars from the Hialeah plant, but the railroads scorned the business because only shifting

charges—that is, no freight rate charge —could be applied. To overcome the transportation problem, a specially designed hopper bottom trailer-truck was purchased, with a lime-carrying capacity of 18 tons. Special hopper bottom connections permit pneumatic unloading directly to bins.

The average lime dosage for both plants is 1,400 lb/mil gal. The lime plant averages 75 tons per day for approximately 330 days, for a yearly production of 24,750 tons. This tonnage will treat an average of 97 mgd. Average consumption during 1958 was 83.5 mgd, with a peak day of 116 mil gal. During April 1959, the average-day demand was 99 mil gal, and on May 5, 1959, an all-time peak demand of 125 mil gal was reached.

By 1960 the capacity of the two treatment plants will be 160 mgd. It is estimated that by 1963 it will be economical to construct a second lime plant at the Alexander Orr Jr. Treatment Plant. In May 1959, a site for a third treatment plant was acquired at a cost of $256,000. Planning engineers estimate that this plant should be in operation, with at least half of its ultimate capacity of 100 mgd, by 1965. With this new plant located adjacent to the existing Hialeah plant, transportation of lime will be reversed as excess lime from the Alexander Orr Jr. Treatment Plant is brought to the Hialeah plants.

From Table 4 it can be seen that investment in plant has increased over the years by some $64,000. The extra costs include the purchase and installation of a second centrifuge, an increase in the height of the storage silo and bucket elevator to provide additional storage, and the provision of a vibrating root separator at the wash mill.

Reference

1. AULTMAN, W. W. Reclamation and Re-Use of Lime in Water Softening. *Jour. AWWA*, 31:640 (Apr. 1939).

Survey and Analysis of Well Stimulation Performance

Louis Koenig

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Louis Koenig, Research Consultant, San Antonio, Tex. This article is the first of a series on various aspects of well stimulation, presented in summary by the author at the Annual Conference. Succeeding articles will also be published in the Journal.

THE study reported here grew out of a more general study in which the possible effect of new technologic advances on ground water production was considered.[1] There is a close similarity between the technology of crude-oil production and the technology of ground water production. Both deal with the flow of fluids in porous underground formations; the physical laws governing the flows are identical (although the mathematical expressions for the flow of crude oil are more complicated), and the wells used are nearly the same for both technologies and are constructed by similar methods. It seemed likely, therefore, with allowances for recognizable and predictable differences, that some of the techniques developed for crude-oil production should be applicable to ground water production, and, conversely, that some of the ground water techniques might be utilized in the oil industry. Indeed, the net direction of such an exchange could be readily predicted, for the oil industry has historically expended a much greater effort in well research and development than has the water industry.

Preliminary Survey

In view of the foregoing considerations, a critical preliminary analysis was made of existing and emerging techniques in crude-oil production to assess the extent of their applicability to ground water production. One of the more outstanding techniques was well stimulation, known variously in the water supply field as well development, redevelopment, or rehabilitation. It was estimated that more than 90 per cent of the approximately 600,000 existing oil wells have been stimulated, some of them many times, in order to increase their production. The frequency of stimulation of the approximately 15,000,000 water wells in the United States could not even be guessed at, but it was thought to be very small. This was also thought to be true of the approximately 400,000 municipal, industrial, and irrigation wells in the nation. The question naturally arose whether there was a real reason for the limited application of a proven technique, or whether it came about largely because the well owners and those who make decisions for them were unaware of the possibilities of stimulation. That the latter was indeed the situation was borne out during the course of the study; in the hundreds of articles that were reviewed on oil well hydraulics and oil well stimulation, not a single reference to literature on water well hydraulics or water well

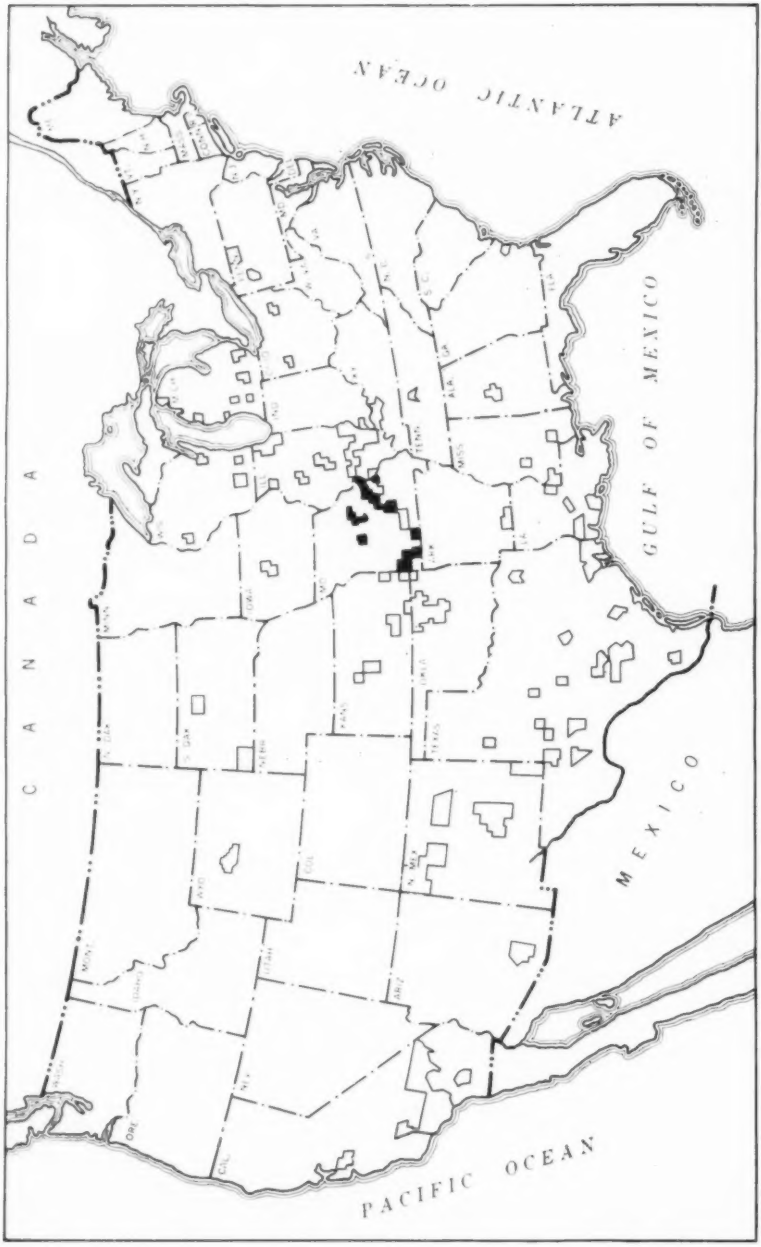


Fig. 1. Counties Included in the Water Well Stimulation Survey

The blackened counties are those in which stimulation practices had been studied prior to Aug. 1, 1957; other outlined areas are those covered by the author's survey up to Jun. 30, 1959.

stimulation was found. Conversely, in the scores of articles on water well hydraulics and stimulation reviewed, only a handful of writers, notably Mylander,[2, 3] referred to oil industry techniques. Apparently, practitioners in the two fields do not read, or contribute to, one another's journals.

Inquiry among water well owners, water well drillers, and ground water hydrologists revealed not only that the extent of water well stimulation was unknown, but also that opinions and experiences on the advantages of stimulation techniques were both vague and varied. Further inquiry in the ground water field revealed that this condition was only one manifestation of a much larger characteristic of those concerned with ground water supplies—namely, a pronounced isolationism. This trait is not confined to well drillers; it exists also among well owners, hydrologists, and engineers—even the most competent. These men may have a detailed knowledge of conditions in, and techniques applicable to, their particular area, but they often exhibit a complete lack of knowledge or interest in other fields, in the mistaken notion that conditions encountered elsewhere have no application at home.

The prevalence of this isolationist condition leads to a number of logistic propositions. First, it is likely that after such pronounced inbreeding a little exogamy would be beneficial. It is possible that some of the techniques developed in one territory may be applicable in others. Moreover, it is possible that techniques which have been written off as failures in one geographic region may be found perfectly applicable in another. Therefore, some stirring up, from the outside, would probably be beneficial and could certainly do no harm. Indeed, examples of the benefits of such stirring up have already arisen from the activities of this survey. Second, as long as the ground water field presents so fragmented a picture, the development and introduction of new techniques will also be fragmentary. High-level research and development work is expensive, especially in the ground water field, and the technologic industries, such as the chemical and mechanical industries, do not risk funds without making some attempt to predict the potential return. This ordinarily involves an analysis of the total national market. No such analysis is possible in the ground water supply field, both because of poor statistics and because of the aforementioned isolationism. Therefore, any attempt to generalize nationally on an aspect of ground water supply and to see the similarities through the differences should be beneficial in providing incentive for the inventive technologic industries to carry on useful research.

Before this survey was begun, there had been reports in the literature concerning water well stimulation, all of which described procedures and results for one well or for very few wells in a given location. These have the same defects as reports from drillers and individual well owners—that is, it is impossible to draw any general conclusions from them as to the effectiveness of water well stimulation. Grohskopf,[4] however, has collected and studied data on 36 cases of pressure acidizing of limestone wells in fifteen Missouri counties. He and his associates at the Missouri Geological Survey were pioneers in the field of pressure acidizing of water wells. From his data on geographic coverage, shown by the blackened areas on the map in Fig. 1, a distribution curve was constructed, showing the percentage of cases in

which the improvement fell between specified values. According to the statistical analysis, failures amounted to 3 per cent, the median improvement was 100 per cent and the best 10 per cent of the tries showed more than 850 per cent improvement over the production immediately before treatment. Other data revealed that stimulation typically cost about a fourth as much as the cost of a new well. This means that as the median improvement the equivalent of two producing wells was obtained for an expenditure of 125 per cent of the price of one well. There was, however, one chance in six (16 per cent) that the increase in production would not be as great as 25 per cent and, therefore, that stimulation would be uneconomical. The results of this analysis were so favorable that an obvious question presented itself: Are such results to be found only for pressure acidizing treatments of limestone wells in Missouri, or would similar results be found for other types of stimulation treatments, in other formations, distributed throughout the United States? It was this question that the author's survey set out to answer.

Stimulation Methods

Stimulation was defined for this study as treatment of a well by mechanical, chemical, or other means for the purpose of reducing or removing an underground resistance to flow. The term was chosen because it is the standard term of the crude-oil industry and there is a much more extensive literature on oil well stimulation than on water well treatment. Furthermore, the water supply field does not have a comprehensive term that denotes all that is meant by stimulation. Comparable terms in the water supply field are development, redevelopment, rehabilitation, or reconditioning. Development usually means some treatment applied upon completion of the well. Redevelopment means treatment applied at some subsequent time, ordinarily after a well has declined in production, although rarely when a well has become unsatisfactory in production without having declined. Rehabilitation and reconditioning not only imply a treatment after completion of the well but they may mean complete reconstruction of a well, as, for example, by removing and replacing the screen or casing, deepening the hole, or enlarging the well. Such operations, which are also part of what the oil man calls "workover," are not included in the definition of stimulation, which is confined to treatment of an existing well as is, not its reconstruction. Among ground water technologists, the terms, "development" and "redevelopment," also include treatment of a well for the purpose of clearing the produced water of turbidity, sand, sediment, or other impurities introduced during drilling. The term, "stimulation," as used here, does not include these operations, except insofar as they are necessary for removing an underground resistance to flow.

As the study progressed, the methods of stimulation reported fell into five major categories. They are, in order from the more familiar to the less familiar, surging, shooting, vibratory explosion, pressure acidizing, and hydraulic fracturing.

Surging

In surging are included those methods which involve movement of water through the formation. There are numerous methods of surging, with and without the help of chemicals. The

simplest consists of merely high-rate production of the well to flush out movable particles, such as sand. Typical surging however involves a movement of water back and forth through the formation, accomplished with a surge block, air pressure, or by starting and stopping the pump. Included in the surging category are those treatments in which chemicals are placed in the well to act rather close to the well face. Chemicals used include phosphates, chlorine, wetting agents, and acids. The number of instances of surging found in the survey was not great enough to allow a breakdown and analysis by type of surging or type of chemical used.

Shooting

Shooting consists of setting off massive charges of explosive in the well. Among the explosives used are various forms of dynamite, nitroglycerin, and TNT. Also used is a powerful, high-velocity explosive,* fabricated in the form of a string to produce a linear explosion as distinct from a point explosion.

Vibratory Explosion

Vibratory explosion is a special form of shooting in which the explosive is divided into quite small charges and arranged to fire in rapid sequence, thus producing a vibrating effect on the casing and possibly on the formation itself.[5-10] At the same time, owing to the release of gas from the explosion, a bubble is created which expands and contracts through an equilibrium position with an amplitude which is gradually damped out. The effect of the vibratory explosive is to prolong greatly the high-amplitude phases of the bubble cycle; the expansion and contraction are said to produce a strong surging action in the formation precisely during the period when the vibrations are knocking particles and deposits free. Because about 300 case-histories of the use of vibratory explosion were available, and because the method seemed particularly likely to be applicable elsewhere than in Southern California, although its use has thus far been restricted almost entirely to that region, the instances of its use were included under a separate category.

Pressure Acidizing

Pressure acidizing, the first of the advanced techniques borrowed from the crude-oil industry, may be applicable to water wells. Pressure acidizing is treatment with large volumes of acid solution, at high rates of injection into the formation and at correspondingly high pressures, producing deep radial penetration. The acid typically used is a 15 per cent solution of muriatic acid to which an inhibitor has been added to prevent the acid from attacking the metal parts of the well structure while allowing it to dissolve the iron, carbonate, and other acid-soluble minerals. Gelling agents are commonly added to modify suitably the flow properties, and retarders may be used to slow down the action of the acid so that at least some of it reaches the extreme depth of penetration of the fluid without losing its dissolving power. Pressure acidizing can be applied only when the formation to be treated is sealed off from overlying formations. If the formation is not sealed, the acid being pumped under pressure into the

* Primacord Bickford detonating fuse; manufactured by Coast Mfg. & Supply Co., Livermore, Calif., and Ensign-Bickford Co., Simsbury, Conn.

well will simply rise up through the overlying formations and will not penetrate radially far from the well. The well itself must also be sealed, usually by cementing the annulus between the casing and hole.

Hydraulic Fracturing

Hydraulic fracturing is the most advanced of the techniques used. It was introduced into the oil industry only about 8 years ago and has since been used on thousands of oil wells. It consists of injecting fluid into the well under such a high pressure that the formation is actually parted, or fractured. The pressure required is 1 psi or less for every foot of overburden. Special gelling agents and other additives are used in order to reduce the flow necessary to generate the required pressure. When the pumping pressure is released, the formation usually returns to its original position and the fractures close up. Sand is added to the fluid, however, and remains in the fractures, propping them open permanently. The fractures are believed to be only a few millimeters wide but they may extend for hundreds of feet and be either horizontal or vertical. The permeability of a properly propped fracture may be 1,000–20,000 gpd/sq ft.

Survey Data

The basic data for the survey consisted of case histories of individual stimulation jobs. Well-servicing companies, drillers, and state and federal geological survey personnel provided leads to stimulation jobs. Final information was obtained from the water well owners themselves or their engineers. The followups ordinarily uncovered additional case histories. An effort was made to avoid any possibility of bias by preselection of the cases and by including failures. The survey results may therefore be considered conservative. The standard check list used in the survey contained 80 items pertaining to the well, the formation, and the water production parameters. In addition, there were up to 20 items concerning the stimulation method used.

It would have been highly desirable to have nonequilibrium pumping or recovery tests on each well for a computation of transmissivity and efficiency characteristics. Only very few water wells have had the benefit of such measurements, however, and an extremely small number of stimulation treatments have been so treated. Accordingly, it was decided to utilize the radial-flow equilibrium formula in the form of the modified Thiem formula [11] to compute the quantity $\bar{m}\,P_f$, in which $\bar{m}$ is the average thickness of the saturated part of the water-bearing material in the circle of influence, in feet, and P_f is the coefficient of permeability (here called the permeation factor), in gallons per day per square foot. In the ideal situation, the term $\bar{m}\,P_f$ corresponds to the Theis coefficient of transmissibility T (here called the transmission factor). The terms permeation factor and transmission factor are used in order to avoid any implication that they represent quantities derived from nonequilibrium tests. Both T and P_f are quantities representing characteristics of the hypothetically ideal formation which would make the ideal well behave as the actual well behaves. It was also assumed, according to a widely used convention, that the radius of influence was equal to 1,000 ft in all instances. The author can find no document that justifies the wide use

of this convention, but it was not necessary for this study, because observation wells other than the producing well were reported in the survey.

Performance Criteria

The criteria chosen for analysis of technical performance were the performance of the well originally, immediately prior to treatment, and immediately after treatment. Performance is measured by the transmission factor, which is a specific capacity corrected for well diameter. This means that the comparison is substantially the same as a comparison of production, in gallons per minute, of wells all with the same hypothetical drawdown. Some of the available data showed that the specific capacity was not constant with changing production. This made interpolations or extrapolations necessary in order to relate all computed specific capacities to the highest noted drawdown. The effect of this manipulation usually gives a favorable picture of stimulation performance as defined below.

For some cases, the specific capacity was not available, because either production or drawdown data were lacking. For these cases, it was assumed that the results being compared related to identical drawdowns or identical productions.

Types of Wells in Sample

Some of the wells studied were not water-producing wells but injection wells, used for disposal or for waterflood injection. Disposal wells have the same hydraulic characteristics as water-producing wells, except that the production and drawdown terms are negative. The specific capacities computed from operating parameters are exactly the same as would be obtained if the wells were operated as producers. The hydraulics of injection wells is not exactly similar to that of producing wells because two-phase flow is involved and there is an anomalous pressure drop at the interface between the water and the oil phase. Furthermore, for most of the injection wells it was not possible to compute the specific capacity. Instead, only an "injectivity index," or the ratio of injection rate to well head pressure, was calculable. This corresponds to using, for a producing well, the ratio of production to lift, in place of the ratio of production to drawdown—that is, specific capacity. The former ratio is the one of practical interest in injection well operation. Furthermore, changes in that ratio will be less than the corresponding changes in specific capacity and to that extent, therefore, use of the injection index for comparisons leads to a conservative evaluation of stimulation performance.

Characteristics of Sample

Although 870 examples of water well stimulation are included in the survey reported here, not all of them contained information from which one or more of the criteria mentioned above could be computed. For the 483 wells that provided data used in the results reported below, a breakdown according to types of well, aquifer types, and stimulation type is given in Table 1. The geographic areas in which the wells are located are shown by the cross-hatched portions of the map in Fig. 1. Data were received from 141 counties in 24 states.

It is not claimed that the surveyed wells constitute a normalized sample—that is, one in which the proportion of the various types of wells, aquifers,

treatments, or other characteristics is the same as that of all wells in the United States. Indeed, water well statistics are so poor that it is quite impossible to determine what the national characteristics are. It is known, however, that the survey sample is quite deficient in surging data, as it is very likely that more wells have been stimulated by surging than by all other methods. Good records are less likely to be kept for surging than for the more advanced methods. The sample is also deficient in coverage of unconsolidated formations, in which the bulk of the nation's wells are located. For the special case of vibratory explosion, it is known that the survey sample covers 20 per cent of all instances of its use.

TABLE 1

Breakdown of 483 Wells Surveyed According to Use, Aquifer, and Type of Stimulation Used

Category	Percentage of Total Wells
Use	
Brine production	3.7
Disposal	3.7
Waterflood injection	8.9
Waterflood source	0.2
Industrial (nonpotable)	12.4
Irrigation	12.0
Potable	51.9
Unknown	7.2
Aquifer	
Consolidated (undifferentiated)	6.4
Consolidated limestone	15.4
Consolidated sandstone	38.4
Unconsolidated	27.6
Unknown	12.2
Treatment	
Hydraulic fracturing	9.5
Pressure acidizing	29.8
Shooting	27.2
Surging	13.9
Vibratory explosion	10.6
Unknown	9.0

Representation of Results

The results of the survey are expressed as cumulative frequency distribution curves for the various criteria of treatment performance. The first criterion is the ratio between the specific capacity immediately after treatment, A, to the specific capacity immediately before treatment (B). This measure of performance (A/B) is termed the "improvement ratio." The frequency distribution is plotted in Fig. 2, which will be discussed as an example of the succeeding figures. The percentages of all cases that have an improvement ratio less than the value indicated on the ordinate are plotted on a probability scale. The ordinate on this graph (Fig. 2) is the improvement ratio A/B—that is, the ratio of the specific capacities, which is equal to the ratio of the transmission factors as well as the ratio of the permeation factors. Such a curve gives the complete pattern of distribution among values of the criterion, but three points on the curve are of particular interest. The point at which the curve crosses the 1.0 improvement ratio represents the percentage of failures, or 11 per cent. This signifies that in 11 per cent of the 455 treatments plotted in Fig. 2, the treatment failed to improve the specific capacity over its value immediately before treatment. In some instances there was an actual decrease in specific capacity. The second check point is the criterion value at which the curve passes the 50 per cent line. This is the median value, such that half of all cases have a criterion value less than this value and half of them have a value greater. In Fig. 2, half

of the 455 treatments showed improvement ratios of less than 1.97 and half greater than 1.97. This check point shows how successful treatment is on the average, or in the typical well. The third check point signifies how good the treatment can be under very favorable circumstances. The 90 per cent value is chosen to represent this.

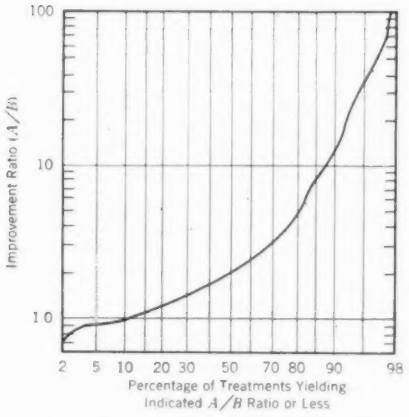


Fig. 2. Cumulative Frequency Distribution of Improvement Ratio (*A*/*B*) for 455 Instances of Stimulation

The improvement ratios of the individual treatments are arranged in order of ascending magnitude. As can be seen, 11 per cent of the treatments had an improvement ratio of A/B ≤ 1, *indicating no improvement. The overall median improvement ratio was 1.97; for the best 10 per cent, it was 11.9.*

In Fig. 2 the curve crosses the 90 per cent line at an improvement ratio of 11.9. This signifies that in the best 10 per cent of the cases the specific capacity of the treated well was about twelve times that of the untreated well.

This probability curve may be considered as showing the odds, judged by past performance, for obtaining any given improvement ratio by stimulation treatment, but there are no physical laws determining the shapes of the curves; they simply represent actual experience. In Fig. 2, which covers all types of treatments in all types of formations, about one treatment in nine failed and in the median, or typical, treatment the improvement was almost 100 per cent.

Figure 3 shows comparative breakdowns of this same criterion for wells in consolidated and those in unconsolidated formations. It is immediately apparent that greater success has been achieved in stimulation of wells in consolidated formations. There are greater failures in the unconsolidated formations, a lower median improvement ratio, and much lower improvement of the best 10 per cent.

In Fig. 4 the experience in consolidated formations alone is shown separately for limestone and sandstone. Although the medians and failures are about the same, it can be seen that the best performances in sandstone are considerably better than the best performance in limestone. It should be understood that certain types of treatment are more commonly used in sandstone formations, such as shooting and hydraulic fracturing, whereas other types, typically pressure acidizing, are common in limestone formations. Accordingly, the superiority of the best performances in sandstone may represent the superiority of hydraulic fracturing or shooting techniques over acidizing techniques. In this connection it should be reiterated that these curves represent only actual experiences, and it cannot be assumed that the techniques used were the best techniques for the conditions.

Figure 5 is a breakdown of results according to certain of the stimulation methods. It is apparent that surging has the poorest performance history, with 24 per cent failures and a median improvement ratio of only 1.20. Even the best 10 per cent of performances for surging show only a 3.0 improvement ratio, compared with about 8.0 for shooting and vibratory explosion. dent that the record of experience with these advanced techniques is considerably superior to the record of more familiar techniques (Fig. 5). Again, it should be emphasized that the curves represent only the treatments as they actually occurred and do not purport to be statistically representative performance ratings for the various techniques. For example, it happens that very few

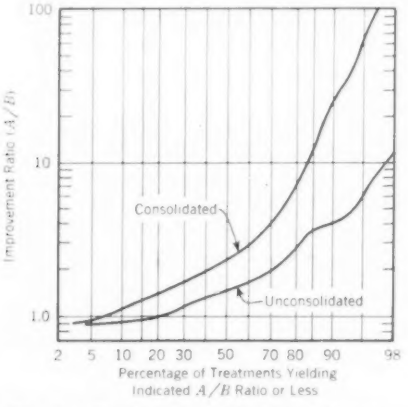


Fig. 3. Performance of Stimulation in Consolidated and Unconsolidated Aquifers

Each curve is a cumulative frequency distribution of A/B *ratios (see Fig. 2). The median improvement in consolidated aquifers (259 treatments, 7 per cent failures) was 2.41; in unconsolidated aquifers (130 treatments, 20 per cent failures) it was 1.45.*

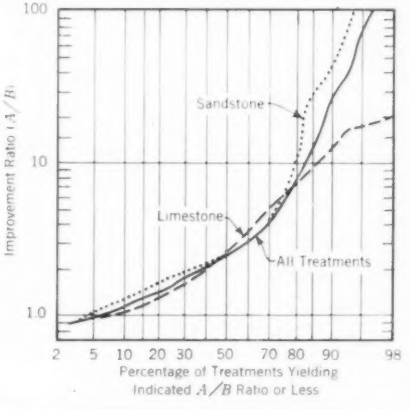


Fig. 4. Performance of Stimulation in Two Types of Consolidated Aquifers

The solid curve (see Fig. 3) is for all 259 treatments in consolidated aquifers. The median improvement ratios were: 166 treatments in sandstone, 2.40 (5 per cent failures); 66 treatments in limestone, 2.50 (8 per cent failures); all 259 treatments, 2.41.

Again, it is quite likely that surging, being a home remedy, is somewhat indiscriminately applied under all sorts of well conditions, and that, because it is cheap, it is applied in situations where the risk of failure could be relatively great.

In Fig. 6 the corresponding relationships are shown for hydraulic fracturing and pressure acidizing. It is evi- producing water wells have been hydraulically fractured, and the hydraulic-fracturing data in Fig. 6 are drawn largely from experience on waterflood sources and injection and disposal wells. Many of these wells operate in regions of much lower permeability than is considered useful for productive wells. It is not to be claimed that the fracturing techniques used on these tight formations would necessarily

show similar high performance levels if applied to the more permeable formations characteristic of most producing wells.

A second criterion that may be of value in comparing stimulation results is the relationship of the production of the treated well to the production of the original well. The ratio of the specific capacity after treatment, A, to the specific capacity of the original well, O, is also an improvement ratio, A/O. Figure 7 shows the cumulative frequency distribution curve for this improvement ratio. The upper line shows, for comparison, the A/B ratio, and the lower line shows the A/O ratio. It may be seen that 43 per cent of the stimulation treatments failed to bring the well up to the specific capacity of the original well. It should be recognized that both of these curves contain treatments on two conditions of wells. One is a treatment of a well that has just been completed and whose specific capacity is for some reason unsatisfactory. The other is a treatment of a well that has been in use for some time and whose specific capacity has declined or become unsatisfactory because of an increase in demand. If the data prove sufficient, it may be useful, in later studies, to separate out new wells from declined wells to see if meaningful relationships can be established. It should also be pointed out that some of the 226 treatments in the A/O curve are not those included in the 455 of the A/B curve. This observation applies rather generally to the curves in this study. In Fig. 7 it

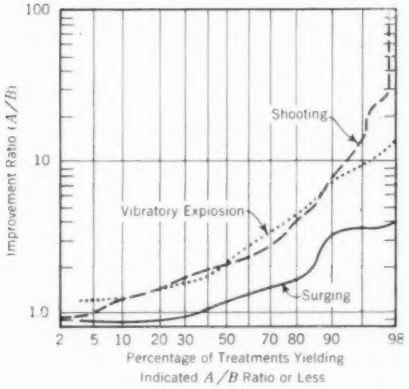


Fig. 5. Performance of Surging, Shooting, and Vibratory Explosion

The curves are cumulative frequency distributions of A/B *ratios for 79 surging, 120 shooting, and 51 vibratory-explosion treatments, respectively. The median improvement ratios for these methods were (in the same order): 1.20 (24 per cent failures), 2.21 (5 per cent failures), and 2.22 (no failures).*

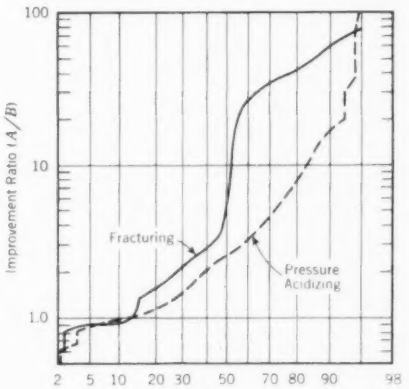


Fig. 6. Performance of Pressure Acidizing and Fracturing

The median improvement ratio for fracturing (40 treatments) was 5.00; for pressure acidizing (133 treatments) it was 2.61. Failures for each method amounted to 13 per cent.

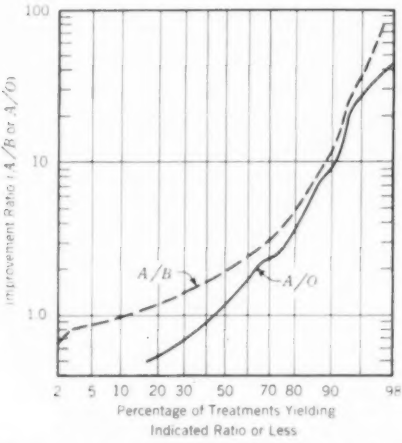


Fig. 7. Cumulative Frequency Distribution of Improvement (*A/B* and *A/O*) Ratios for Stimulation Treatments

Data were not available for an evaluation of all treatments by both A/B *and* A/O *criteria; the treatments represented in the two curves are not, therefore, all the same ones, although there is an overlap. The dashed curve (455 treatments,* A/B *criterion) has a median improvement ratio of 1.97 (11 per cent failures); the solid curve (226 treatments,* A/O *criterion) has a median improvement ratio of 1.20 (43 per cent failures).*

means that not all of the 455 treatments for which *A/B* data were available also had *A/O* data, and furthermore that some of the 226 treatments for which *A/O* data were available did not have the corresponding *A/B* data.

In Fig. 8 a breakdown of *A/O* ratios by type of formation is shown. Again it is seen that the chance for success in unconsolidated formations is quite small compared to the chance in consolidated formations. In 79 per cent of the wells, stimulation treatment failed to bring unconsolidated formations up to the performance of the original wells.

In Fig. 9 is shown the breakdown of the *A/O* criterion by treatment type. A pattern similar to that for the *A/B* ratio emerges, except that the level of performance is lower for each method other than hydraulic fracturing. The highlight points for the two criteria described above are presented in Table 2.

Incremental-Improvement Ratio

A third criterion that may be analyzed is the increase of specific capacity

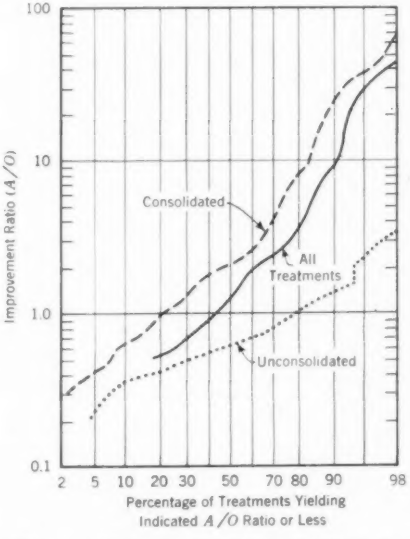


Fig. 8. Performance of Stimulation in Consolidated and Unconsolidated Aquifers (*A/O* Criterion)

The dashed and dotted curves are cumulative frequency distributions of A/O *ratios for treatments in consolidated and unconsolidated aquifers, respectively. The solid curve is that of Fig. 7. The median improvement ratio for consolidated aquifers (131 treatments, 21 per cent failures) was 2.15; for unconsolidated formations (81 treatments, 79 per cent failures) it was 0.62.*

achieved by treatment compared to the specific capacity of the original well—that is, the specific capacity achieved by constructing the well in the first place. If a well field of numerous identical wells is assumed, this criterion indicates how many of these wells must be stimulated in order to achieve the same additional production that would be achieved by drilling one additional new well. Mathematically, the criterion is the ratio of incremental specific capacity to original (I/O). Figure 10 shows the frequency distribution of this criterion. The percentage figures on the 1.0 ordinate do not have the same meaning as before, but refer to the percentage of treatments for each curve having a ratio greater than 1.0. From the curve for all treatments it can be seen that there is about a 30 per cent chance that one stimulation treatment will add a specific capacity equivalent to at least one original well. For consolidated formations, this chance rises to 36 per cent, whereas for unconsolidated formations there is only a 5 per cent chance of obtaining the equivalent of one additional well from one stimulation treatment. In the median it takes about three stimulation treatments in consolidated formations to add specific capacity equivalent to two original wells; whereas about eight wells must be stimulated in unconsolidated formations to add specific capacity equivalent to one additional new well. The reason that the curve for all 205 treatments rises above both the curves for consolidated and unconsolidated formations is that the 205 treatments include a number of wells for which the type of formation was not known and which happen to have rather high I/O ratios.

Figure 11 shows the same I/O criterion by treatment type. The percentage figures on the 1.0 ordinate have the same meaning as in Fig. 10. For example, there is a 43 per cent chance that pressure-acidizing treatment will yield the equivalent of an original well. It is to be noted that these statements apply to the original performance of the well being treated and not to the performance to be expected from other wells drilled in the same field, in which the treated well might be an exception.

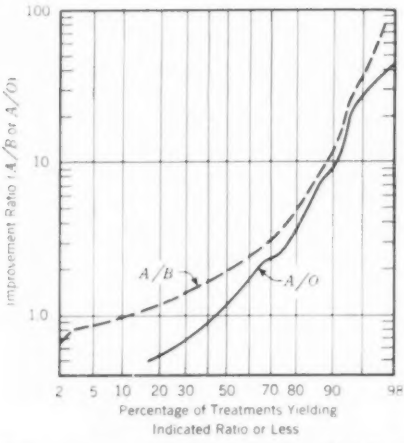
TABLE 2

Evaluation of Various Stimulation Techniques by A/B *and* A/O *Criteria*

Stimulation Method	Performance by *A/B* Criterion			Performance by *A/O* Criterion		
	Median for Sample	Best 10% of Sample	Failures *per cent*	Median for Sample	Best 10% of Sample	Failures *per cent*
Surging	1.20	3.4	24	0.66	2.5	75
Shooting	2.12	8.2	5	1.50	4.6	32
Vibratory Explosion	2.25	7.6	0	0.61	1.5	61
Pressure Acidizing	2.61	16.1	13	1.96	8.1	29
Fracturing	5.00	60.0	13	13.00	51.0	6
All methods	1.97	11.9	11	1.20	8.9	43

Interpretation of Results

Of course, it might be objected that the results of the survey, for example



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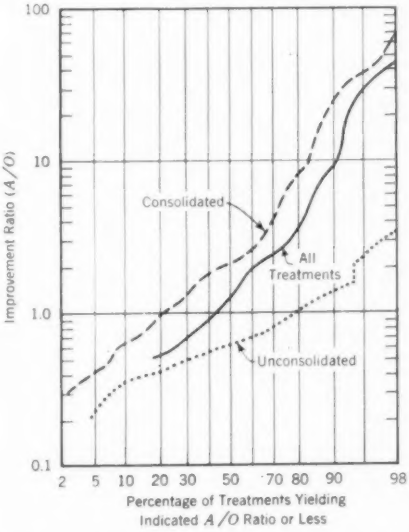

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Figure 11 shows the same I/O criterion by treatment type. The percentage figures on the 1.0 ordinate have the same meaning as in Fig. 10. For example, there is a 43 per cent chance that pressure-acidizing treatment will yield the equivalent of an original well. It is to be noted that these statements apply to the original performance of the well being treated and not to the performance to be expected from other wells drilled in the same field, in which the treated well might be an exception.

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Fracturing	5.00	60.0	13	13.00	51.0	6
All methods	1.97	11.9	11	1.20	8.9	43

Interpretation of Results

Of course, it might be objected that the results of the survey, for example

the 1.97 median for the *A/B* ratio, having come from 455 stimuation treatments, might prove to be quite inconsistent with the results for the next 455 cases. No absolute refutation of this objection is possible. The sample was accumulated simply in chronological order. The survey method has been explored for possible bias toward high or low performance results, and there appears to be no bias in any of the following: age of wells, dates of treatment, geographic location, ease of obtaining data, category of ownership, service company performing stimulation job, use of published or unpublished data, or the mode of soliciting data.

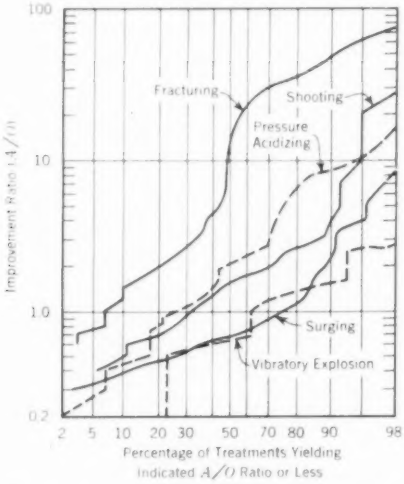

Fig. 9. Performance of Various Stimulation Methods (*A/O* Criterion)

Each curve is a cumulative frequency distribution of A/O ratios for a different stimulation method. The median improvement ratios for each method were: fracturing (31 treatments, 6 per cent failures), 13.0; pressure acidizing (49 treatments, 29 per cent failures), 1.96; shooting (59 treatments, 32 per cent failures), 1.50; surging (68 treatments, 75 per cent failures), 0.66; vibratory explosion (13 treatments, 62 per cent failures), 0.61.

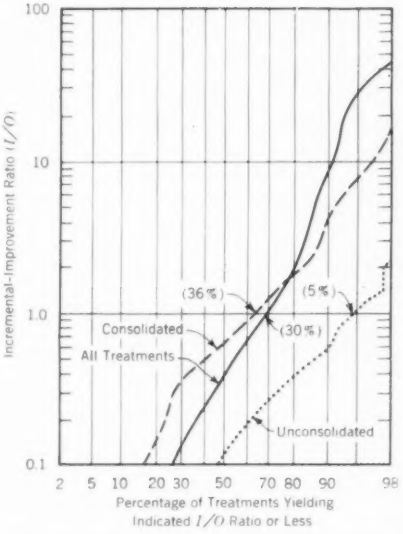

Fig. 10. Cumulative Frequency Distribution of Incremental-Improvement Ratios (*I/O* Criterion) for 205 Stimulation Treatments

The median incremental-improvement ratios were: consolidated (96 treatments), 0.70; unconsolidated (81 treatments), 0.12; all 205 treatments, 0.43. The percentages accompanying each curve represent the probability (in the given sample) that stimulation will yield a production increase equal to, or greater than, the production of the original well.

Although the results from the next 455 hypothetical wells are unknown, it might be instructive to consider what the answer would have been had that question been asked at various stages during the collection of the data. For this purpose the data were analyzed in chronological order to determine what

the A/B median would have been if analyzed at several stages during their collection. The results of this analysis are shown in Fig. 12, where the A/B medians for the first 100 wells, the first 200, and so on, are plotted. It can be seen that the median steadily decreases as the number analyzed increases, and that the results would have been much more favorable had they been reported after, for example, the first 100 wells. On the other hand, it can also be seen that the differences between successive points decrease with increases in the size of sample and seem to slope off and approach a value not very far below the value reported (1.97).

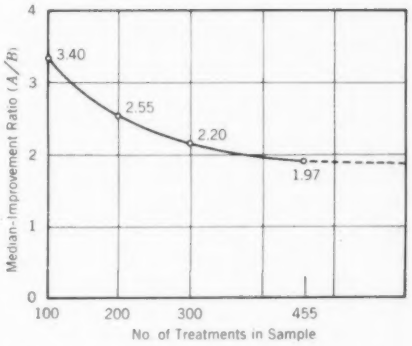

Fig. 12. Trend of Median A/B Ratios According to Sample Size

As can be seen, the curve seems to level off at approximately 1.97.

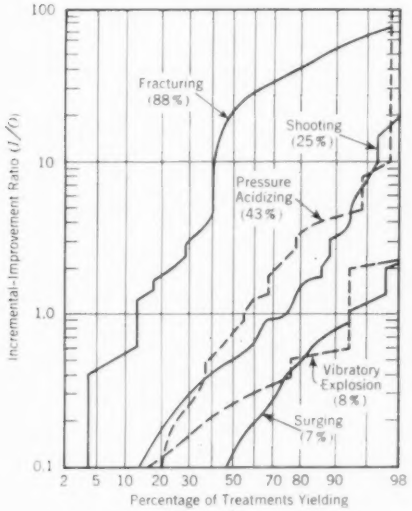

Fig. 11. Performance of Various Stimulation Techniques (I/O Criterion)

The percentages accompanying each curve have the same significance as in Fig. 10. The median incremental-improvement ratios for each technique were: fracturing (25 treatments), 22.0; shooting (52 treatments), 0.50; pressure acidizing (37 treatments), 0.75; surging (65 treatments), 0.105; vibratory explosion (60 treatments), 0.25.

Time-Production Rate Integral

The pertinence of using simple specific-capacity ratios as measures of treatment performance may be questioned. Certainly, both the amount that production has increased and the period over which that increase remains in effect must be considered in analysis. It is quite possible, from the way the data are presented, that they signify nothing more than a momentary increase in specific capacity, which rapidly falls off to the value immediately before treatment.

A more trustworthy method of characterizing stimulation performance has been worked out for treatment of oil wells and involves a comparison of the time–production rate integral. This may be illustrated by an actual example for a water well (Fig. 13). This well started out with a specific capacity

of approximately 107 in the year of its construction, 1924. The specific capacity steadily declined until it was decided to acidize the well in 1937. This brought the specific capacity from 62 to 98 (A/B ratio of 1.53). The specific capacity thereafter declined at a rate slightly slower than that of the untreated well until it was decided to stimulate again in 1950. This stimulation was not so effective. The rate of decline thereafter is unknown, but it is drawn in Fig. 13 at the same rate as the earlier decline of the treated well. If the well had not been stimulated, the specific capacity would presumably have continued to decline along the dashed-line extension of the original decline. Eventually, operation would have become uneconomical and the well would have been abandoned. The position of this cutoff point depends in a complex way on a variety of factors, including lift, demand, power cost, well construction cost, and others. Accordingly, it cannot be calculated without an economic analysis in each case. Such data are not, in general, available, and it is obvious that such a manipulation would tremendously increase the work of making a wholesale study like this one. For a special study, however, of which this illustration was a part, the cutoff point was chosen at a specific capacity 20 per cent of the original specific capacity. For any arbitrarily selected drawdown, the shaded area under the specific-capacity decline curve represents a certain number of gallons of water that could have been produced from the untreated well. The remainder of the area under the

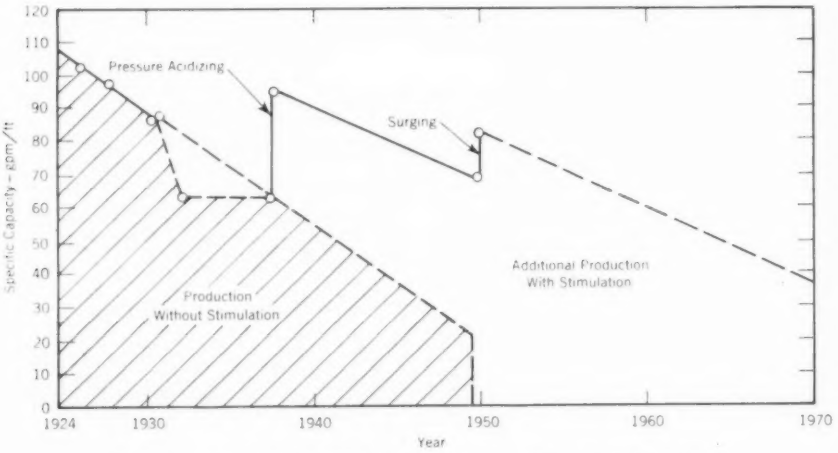

Fig. 13. Example of Production Increase Through Stimulation

For any constant drawdown, the area under the curve of specific capacities, plotted with respect to time, can be taken to be a geometric representation of total production during the lifetime of the well. As can be seen, the application of stimulation to this well almost doubled its total production (and more than doubled its productive life).

curve, unshaded, represents the additional volume made available through the stimulation treatments. By inspection of the shaded and unshaded areas, one can see that the potential production from the well was about doubled by the stimulation treatments (the illustration shows the production only to 1970, not to the chosen cutoff point). An analysis based on such a criterion would undoubtedly be superior for the whole survey, but lack of data precluded the possibility in all but a few special cases. There is nothing in the available evidence, however, to indicate that the rate of decline of a well treated by any method is any greater than the rate of decline of the untreated well.

Summary

A study has been made of the technical performance factors in water well stimulation drawn from 870 actual stimulation cases in 141 counties of 24 states. From the 483 sources providing usable data, cumulative frequency distribution curves were drawn for three criteria of technical performance: (1) the ratio of specific capacities immediately after and immediately before treatment, (2) the ratio of specific capacities immediately after treatment and at the time of constructing the original well, and (3) the ratio of the increment in specific capacity as a result of treatment to the specific capacity of the original well.

For all types of treatments in all types of formations the median ratio indicated a 97 per cent improvement over specific capacity immediately before treatment, and a 20 per cent improvement over the original production of the well. Failures to achieve any improvement over the treated well were 11 per cent, whereas failures to achieve improvement over the original well were 43 per cent. The median increment of specific capacity achieved by treatment was 43 per cent of the specific capacity of the original well.

When considered by type of formation, the data show that success has been definitely greater in consolidated formations than in unconsoliated formations. Based on improvement over the well before treatment, consolidated formations show a median of 141 per cent improvement, whereas unconsolidated formations show only 45 per cent improvement.

When analyzed by treatment type, the data show a quite consistent pattern by all three criteria, the methods, arranged in ascending order of effectiveness, being surging, shooting, vibratory explosion, pressure acidizing, and fracturing.

Water well stimulation has definitely been technically successful; some of the more advanced teechniques that have already been adopted as conventional practice in crude-oil production technology have shown higher performance records than the conventional techniques in the water industry. Judged by the wide geographic coverage of successful stimulation treatments, stimulation could probably be much more widely applied to improve ground water production.

Acknowledgments

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Special acknowledgment is due to William D. Owsley and his colleagues, who readily perceived the potential importance of the study, and have granted permission to publish the results freely. Thanks are also expressed to Jesse Cabrera, who performed with great skill the complicated calculations and statistical analyses. The author is also grateful to the hundreds of well drillers and owners, geologists, hydrologists, administrators of federal and state geological and water surveys, private consultants and others who supplied leads, advice, and data.

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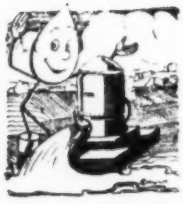

Application of Rotary Drilling to Water Wells

William A. McEllhiney

A paper presented on Sep. 9, 1959, at the Wisconsin Section Meeting, Milwaukee, Wis., by William A. McEllhiney, Pres., J. P. Miller Artesian Well Co., Brookfield, Ill.

IF one were to look through a few issues of *Drilling*, a magazine of the oil industry, or, better still, if one were to study the composite catalogs of equipment and materials offered by manufacturers catering to the oil-drilling contractors, one would soon be convinced that only rotary tools should be used to drill a well. Nevertheless, cable tools and the percussion method are likely to continue to be used for some time to come. The author would guess, however, that in the years to come more and more wells will be drilled with rotary tools. Rotary drilling equipment, as it is known today, was nurtured and developed by and for the oil industry. Rotary tools became an absolute necessity as the industry began to drill deeper and deeper for oil.

It is one thing to drill for oil, which sells for $75 per 1,000 gal at the well head; however, it is quite another thing to drill for water, which sells for approximately 20 cents per 1,000 gal.

The hole size of an oil well is small compared to a water well hole. To make matters worse for the water well contractor, the trend in the oil industry is toward slimmer and slimmer holes. The manufacturers of rotary drills have had to look to the oil industry for a volume market, and, as a result, the water industry has not been given much attention. Rotary tools for water wells have, for the most part, had to go through a home-made, "do-it-yourself" period. These may be some of the reasons why the water industry in the north central area has been slow to utilize rotary drilling equipment. It is only very recently that certain manufacturers have begun to offer a helping hand by building rotary drilling equipment especially designed for water wells. Undoubtedly, more and more attention will be given to the design of equipment to drill the larger-diameter, moderately deep holes required for water wells.

Rotary Test Drilling

In the hands of a skilled operator, a rotary drill is a most useful tool for test hole work. Much information can be obtained from resistivity surveys, and it is possible to eliminate large areas as devoid of water-bearing gravel and sand deposits, but even in favorable areas test holes are necessary to pinpoint productive aquifers and the best locations for individual wells. Rotary-drilled test holes are not only normally less expensive, but they also produce much more information on the formation than anything else—short of a finished pumping well.

The technique of rotary test work is to drill a small 4–4½-in. hole, nor-

mally uncased, through the formation. A record may be kept of:

1. Depth drilled
2. Drilling rate
3. Mud loss
4. Weight of mud
5. Viscosity of mud
6. Behavior of drilling tools
7. Samples of formations
8. Depth of top and bottom of each stratum
9. Static levels
10. An accurate sample of the water in the formation
11. Opinions of a skilled operator.

Although some of the items of information listed above may be unnecessary, it should be pointed out that several of the items are possible, and only possible, when the test hole is drilled with rotary equipment.

The interpretation of the data obtained is for the hydrologists, engineers, and contractors who have had years of experience with test drilling of this type. In general, the fluid loss method of testing for productive sands and gravels is based on the theory that formations that will absorb fluids during rotary drilling are porous and of sufficient permeability to give up water when pumped.

Very heavy gravels and boulders quite often offer obstacles to rotary drilling, and high static water levels may cause trouble. Such conditions are the exception, however, and because a greater amount of detail can be obtained from rotary bores, the rotary method of test drilling it is to be recommended.

Completion of Wells

After the test hole program, final wells must be completed. Tubular wells or gravel-packed wells can be constructed either by straight or by reverse rotary drilling equipment. Artesian formations and extremely rocky materials are about the only things to discourage rotary construction.

To construct a tubular well with straight or reverse circulation of the drilling fluid, it is only necessary to drill one bore in the formation from the surface of the ground down through the producing zone or zones. The bore should be of a size that will accommodate the screen and well casing. No outer casing, with the possible exception of a short curb ring, is necessary. After the casing and screen are in proper position, the well is developed by surging, agitation, and test pumping. Chemicals are sometimes used to break down the mud membrane, which, until the screen and casing have been installed, supports the wall of the well bore. The natural formation then rests against the screen and well casing, and development can be continued by conventional methods. Drilling muds, whether natural or prepared clays or gel-forming colloidal bentonites, give very little trouble in the development of a rotary-drilled well. Occasionally the development may require a little more time, and such chemicals as phosphates or acid may be used to advantage, but by and large the results of drilling with a rotary or cable tool rig are the same.

Reverse Rotary Drilling

Although very little rotary drilling equipment has been designed or manufactured for drilling water wells, the development of the modern reverse rotary drills for large-bore, gravel-packed wells is an exception. More and more wells are being constructed by this method.

The advantages of the reverse-circulation method of construction are manifold. It provides more clean-cut weeping surface on the well bore, particularly in laminated formations. There is none of the bending over of laminated layers that occurs when casings are driven into or jacked out of the formation. Wells can be drilled with larger bores, resulting in larger weeping surface areas, and they can be drilled into deep sand and gravel formations with comparative ease. No outer casing is required; only a curb ring is necessary. Test pumping is normally the only development required. The reverse-circulation rotary drilling method usually costs less than other methods.

Before reverse-circulation rotary drilling can be undertaken, the following conditions must be fulfilled:

1. Accurate test hole data must be available at the site.
2. There must be an ample water supply for drilling.
3. A supply of clay must be available on short notice, if it becomes necessary to use it.
4. A screen of proper dimensions and all fittings must be on the site before drilling is begun.
5. Gravel packing of the proper grade must be available in sufficient quantity.
6. A well casing must be on hand and in condition to be installed immediately.
7. There must be an understanding between all parties before drilling begins. A rotary drill hole will not stand up indefinitely. The work, once begun, cannot be shut down to wait for materials or from decisions out of town.
8. Plans must be made to work, if necessary, around the clock, including Sundays and holidays.

The mechanics of drilling a well with reverse circulation rotary equipment is much the same as augering a hole through a wood plank. A cutting face, or bit, is attached to hollow drill pipe, which is rotated by a power table. The loosened, unconsolidated material is removed from the bore under construction in a stream of water which carries it up the hollow drill pipe and into a pit or pool where it is settled out. The water then returns to the bottom of the bore to complete the cycle of circulation. At all times the pit and bore must be kept full of fluid.

As each increment of depth of hole is cut, a film or thin membrane of mud is deposited on the interior of the bore, which is the weeping surface of the producing zone or formation. This membrane, with a differential head of not less than 6–10 ft between the water table of the natural formation and the liquid level in the bore during drilling, is sufficient to support the walls of the well during construction. Normally, it is not necessary to add clays or any foreign material during construction, but it is well to have some material on hand as a precaution. Occasionally a formation takes water faster than the pit can be supplied with makeup water. The more water available for the pit, the less clay is required.

The ease with which a hole can be made with reverse equipment depends upon the nature of the formation. In general, very little trouble is encountered in drilling or wall stabilization of any material that will take water. The three most troublesome conditions are the presence of boulders, massive

sections of laminated clays, and, particularly, strips with an angular cleavage which are not the same as the bedding plan of deposition, or very heavy compacted clays with imbedded boulders.

Drilled materials are normally removed from the bore through the drill pipe; all material larger than the opening in the drill pipe must be removed by other means. The number and extent of boulders that lie in the path of the drill can mean the difference between a profit or a loss for the driller. A driller must have ingenuity and a great variety of tools to cope successfully with oversized rocks.

Laminated clays do not take water and, therefore, are more likely to cave in. Often a liner must be used to protect the bore. Time is of the essence in drilling through thick beds of such materials, as the extent of caving is a function of the time between cutting the formation and the completion of the well. Rock-laden clays cause abrasion of drilling tools and can be a time-consuming factor in the drilling operation.

Once the bore has been completed, the screen, casing, and gravel packing can be installed in the conventional manner. It has been the author's experience that very little development is necessary to attain maximum yield. Test pumping usually does the job. It is to the credit of drilling contractors and their application of reverse-circulation rotary equipment to gravel-packed wells that the cost of construction is often a fraction of what it was only a few years ago.

Summary

In the water supply and industrial fields, rotary drilling equipment has successfully filled a need; it has reduced costs of test hole work and large-bore, gravel-packed wells. Well work involving straight conventional rotary drilling of large-bore wells (10–20-in. bottoms) in deep sandstone has scarcely been attempted in the Wisconsin area.

There has been a good deal of rotary work in the drilling of private, domestic wells. It was, however, limited to the production of water out of the top consolidated aquifer, where it is not necessary to deal with the problems of a large hole, varied formation, lost circulation, or abrasive sand.

The author feels that rotary equipment deserves a fair trial in the deep-sandstone field. There undoubtedly are contractors who are willing to apply themselves to the task. Right now there is a need for a more complete understanding, on the part of the public, engineers, and owners, to the possibilities of this new method of drilling.

A few years ago, the oil industry began to call for well holes of smaller dimensions. Alloy steels have made it possible for slim-hole wells to equal the production of older and larger bores. A similar approach in water well construction may be a partial answer. Where well production is of the order of 1,000–15,000 gpm, there is a question in many minds as to whether the finished bore should be larger than 15 in. A few years ago, the 1½-in. turbine pump line shaft was limited to 75 hp, but now alloy shafting the same size is safely used for 125 hp and even 150 hp. The expense of rotary drilling is a function of the size of bore, and the same can be said of cable tool drilling. The economic advantages to the rotary process are

offset by lack of volume work in the foreseeable future.

It is possible to drill deep sandstone wells with rotary equipment with very little change in the usual specifications. Under certain conditions it may be a preferred method. Hole enlargement in producing sandstones should give even more productive results when done with rotary tools, than where explosives are used with cable tool cleanout. It may soon be possible to drill very large holes of 30–60 in. with reverse rotary equipment; this would certainly answer many hole enlargement problems.

The author's firm is now completing a contract for four bores 54 in. in diameter, five bores 36 in. in diameter, and sixteen bores 18 in. in diameter, all approximately 340 ft deep. These bores are through a drift, Niagaran limestone, and Maquoketa shale formation. They were drilled with reverse-circulation equipment, and the finished bores were well within standard straightness limitations. They were drilled at very reasonable cost. There is no reason why such bores could not be drilled to much greater depths through the prevailing formation in Wisconsin.

Interpretation of Boundary Effects From Pumping Test Data

S. M. Lang

A contribution to the Journal by S. M. Lang, Hydraulic Engr., Ground Water Branch, USGS, Trenton, N.J. Publication of this article has been authorized by the director, USGS.

THE hydraulic characteristics of an aquifer that define its abilities to store and transmit water are generally determined from the analysis of pumping test data by means of various formulas, of which the most widely used is the nonequilibrium formula developed by Theis.[1] The development of the formula was based, in part, on assumptions that the aquifer pumped is of infinite areal extent and of uniform permeability.

Stallman[2] presented a modification of the Theis formula to extend its application to situations in which the pumped formation is adjacent to another formation of a vastly different transmissibility and the boundary between the formations approximates a straight line. The two most common examples of this type of situation, which are diagrammatically presented by Brown,[3] are: (1) the aquifer that is hydraulically connected with a fully penetrating surface stream and (2) the permeable material of a buried valley abutting the relatively impermeable walls of the valley. In the first example, the line of contact between the stream and aquifer is referred to as a "line source," or a line along which the head on the aquifer remains constant and cannot be drawn down. In the second example, the line of contact between the permeable material and the valley wall is an impermeable barrier across which there can be no flow because the impermeable valley wall effectively limits the extent of the aquifer.

Image Well Model

Stallman's modification and the analytical procedures described by Brown for analyzing data from aquifer tests involving boundaries are based on the image well theory,[4] according to which the hydraulic effects actually caused by the geologic boundaries may be theoretically ascribed to strategically placed imaginary wells. The application of the image well model makes it possible to treat a problem involving boundary conditions like one of a multiple-well system in an infinite aquifer.

Methods and procedures outlined by Stallman and Brown make possible the solution of problems involving one boundary; the hydraulic system may be balanced by the proper positioning of one image well. The resultant drawdown patterns have been described by Lang.[5] Little has been written concerning the multiple-well systems, however, except to indicate the location pattern of image wells resulting from two or more boundaries. For an aquifer having two boundaries, the least number of image wells is three, if the

boundaries intersect at a right angle. For certain vertically-bounded, wedge-shaped aquifers, equations for determining the number of image wells are available. If either two parallel boundaries or more than two boundaries are involved, an infinite number of image wells results.

Nonequilibrium Formula

The Theis nonequilibrium formula is:

$$s = \frac{114.6\,Q}{T} W(u) \quad \ldots\ldots (1)$$

in which s is the drawdown at any point, in feet; Q is the discharge rate of the pumped well, in gallons per minute; and T is the coefficient of transmissibility of the aquifer, in gallons per day per foot.

$$W(u) = -0.5772 - \log_e u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} \cdots$$

$$u = \frac{1.87\,r^2 S}{Tt} \quad \ldots\ldots (2)$$

in which S is the coefficient (dimensionless) of storage of the aquifer; r is the distance, in feet, from pumping well to point at which drawdown, s, is considered; and t is the pumping time, in days.

Transmissibility and Storage Coefficients

Most of the terms in Eq 1 and 2 need no explanation, as they are commonly used in ground water hydrology. The coefficients of transmissibility and storage, however, need further elaboration if their significance is to be fully understood. The coefficient of transmissibility of an aquifer, T, is the rate of flow of water, at the prevailing water temperature, through a vertical strip of the aquifer 1 ft wide and extending the full saturated height of the aquifer under a hydraulic gradient of 100 per cent. The coefficient of storage of an aquifer, S, is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. A diagrammatic representation and more detailed discussion of the hydraulic properties of an aquifer are presented by Brown.[3]

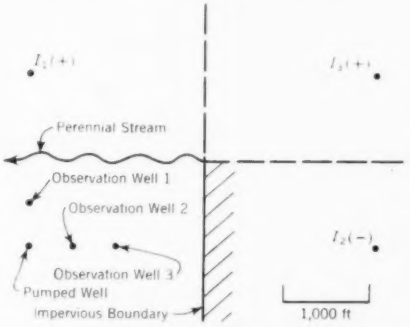

Fig. 1. Plan of Hypothetical Test of an Aquifer Bounded by an Impervious Barrier Intersected at Right Angles by a Perennial Stream

The pumped well yields 1,000 gpm for the test period. Drawdown data for Observation Well 2 are given in Table 1.

Graphical Solution

The nonequilibrium formula may be solved graphically by matching logarithmic plots of s with respect to r^2/t, r^2, or $1/t$ with a logarithmic plot of $W(u)$ with respect to u, usually called the "type curve." The test data are plotted on logarithmic paper identical to that used for the type curve, and with the axes of the papers parallel, the best fit of the test data to the type curve is obtained. From this fit, values of u and $W(u)$ may be determined

from the type curve for any selected point on the graph of observed data and may be used, in conjunction with the observed values for that point, to determine the coefficients of transmissibility and storage. As indicated above, the Theis formula may be used in either of two ways: the hydraulic coefficients may be computed (1) from the drawdown or recovery curve of one well or (2) from drawdowns observed at any one time in a group of wells—that is, from the form of the cone of depression. If, however, boundary conditions are involved, the second method can only be applied to data collected before the cone of depression intersects the boundary. If the aquifer pumped has a very large areal extent and is of relatively uniform thickness and permeability, then the observed values usually will closely approximate the type curve.

A boundary is indicated by a deflection of the observed-data curve from the type curve. The early data that reflect only the effects of the pumping well match the type curve, whereas those data affected by the boundary will depart from the type curve. A departure denoting an increase in the rate of drawdown is the result of a barrier-type boundary (equivalent in effect to a discharging image well), whereas a departure denoting a decrease in the drawdown rate reflects a recharge-type boundary (equivalent in effect to a recharging image well).

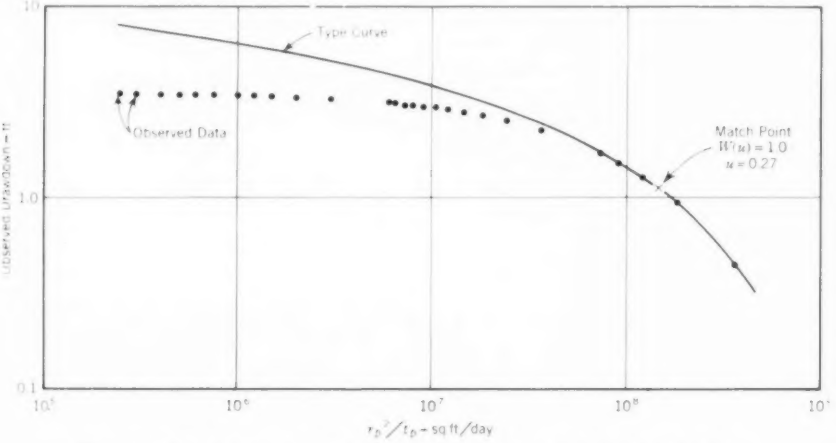

Fig. 2. Match of the Observed-Data Curve to the Theis Type Curve

The later observed data (from Observation Well 2) fall below the curve type, indicating that the first boundary encountered by the drawdown cone is a recharging one.

The magnitudes of the departures from the type curve are calculated, and the departures are plotted as a new curve. The departure curve is then matched to the type curve and, if only one boundary is involved, the departure and type curves coincide. A deflection of the departure curve from the type curve indicates the presence of at least one more boundary, and, therefore, that three or more image wells are necessary to describe the formation.

As indicated above, the interpretation of the deflection of the initially plotted observed-data curve from the type curve, as to the kind of boundary involved, is more or less routine. Such a routine interpretation may, however, lead to serious errors when it is applied to the deflection of the replotted departure curve from the type curve. To illustrate this, a hypothetical test is considered and the procedures needed to compute data from a multiple-well system are indicated.

Hypothetical Example

As shown in Fig. 1, the aquifer tested is bounded by an impervious barrier intersected at right angles by a perennial stream, which fully penetrates the aquifer. The pumped well yields 1,000 gpm for the test period. The complete solution of a pumping test involving boundary conditions requires at least three observation wells. Because the logarithmic data plots are similar for all observation wells, however, only the data plots for Observation Well 2 are presented. The time and drawdown data for Observation Well 2 are given in Table 1.

The drawdown, s, is plotted against distance squared divided by time (r^2/t) on logarithmic paper and then is matched with the type curve. The resulting graph is shown in Fig. 2. The later observed data fall below the type curve (rate of drawdown is decreasing), indicating that the first boundary encountered by the expanding cone of depression is a recharge boundary. In the course of time, the magnitude of the observed drawdown is the result of the effects of all boundaries (as represented by image wells) in addition to those of the pumped well. Because the first boundary is the closest to the pumped well, its effect is much greater than those of more distant boundaries, and it therefore determines the direction in which the observed-data curve will first depart from the type curve. To determine whether additional boundaries are present, the departures of the observed data from the type curve are computed and plotted against corresponding values of r^2/t, and the new curve is matched to the type curve. As shown in Fig. 3, the latter part of the departure curve also deflects downward from the type curve, indicating the presence of a second boundary

TABLE 1

Pumping Time and Drawdown Data for Observation Well 2

Pumping Time *days*	r^2/t (r = 500 ft) *sq ft/day*	Drawdown (s) *ft*
0	∞	0
0.00069	3.60×10^5	0.45
0.0014	1.80	0.94
0.0021	1.20	1.28
0.0028	9.00×10^7	1.54
0.0035	7.20	1.74
0.0069	3.60	2.32
0.010	2.40	2.60
0.014	1.80	2.76
0.017	1.44	2.87
0.021	1.20	2.97
0.024	1.03	3.04
0.028	9.00×10^6	3.08
0.031	8.00	3.13
0.035	7.20	3.16
0.038	6.55	3.21
0.042	6.00	3.22
0.083	3.00	3.39
0.12	2.00	3.45
0.17	1.50	3.47
0.21	1.20	3.50
0.25	1.00	3.51
0.33	7.50×10^5	3.54
0.42	6.00	3.54
0.50	5.00	3.55
0.62	4.00	3.56
0.83	3.00	3.55
1.00	2.50	3.54

and, therefore, of at least three image wells.

Inverted Image Well

The routine interpretation of the deflection of the departure curve would be that a second recharge boundary is present. Such an interpretation would be wrong, however, for, in the example under consideration, the downward deflection indicates a negative boundary and not a positive one.

In order to make the correct interpretation, it is necessary to consider the character of the data plotted. When the observed-data plot is in its matched position on the type curve, the type curve shows the drawdown that would theoretically be produced by the pumped well alone if the aquifer were infinite in areal extent. The departure of the observed data (Fig. 2) from the type curve represents a decrease in the rate of drawdown, which is the result of an influx of water across the recharge boundary. This boundary is simulated hydraulically by imagining an inverted image well, at the same distance from the boundary as the pumped well but on the opposite side, adding water to the aquifer at the same time and rate as the pumped well is discharging water. The departures therefore represent the effect of the buildup in water level caused by the recharging image well. This

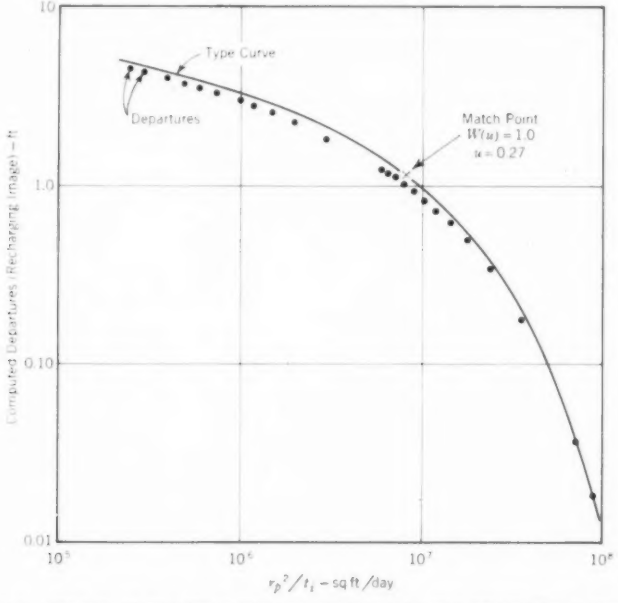

Fig. 3. Match of the First-Departure Curve to the Theis Type Curve

Downward deflection of the latter parts of the departure curve indicates the presence of a second boundary and, therefore, of at least three image wells. Because the plotted departures are related to a recharging image, the first-departure curve represents a a buildup of water level.

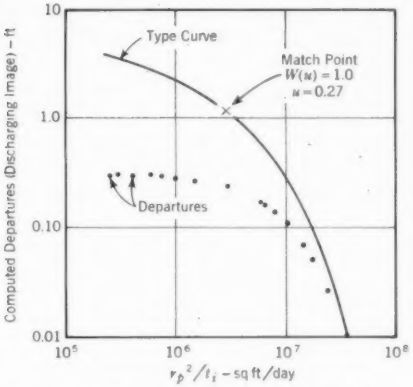

Fig. 4. Match of Second-Departure Curve to the Theis Type Curve

Because the plotted departures are related to a discharging image well, the second-departure curve represents drawdown.

buildup in water level, when algebraically added to the drawdown caused by the pumped well, results in the observed net drawdown.

In its matching position with the first departure curve (Fig. 3), the type curve indicates the buildup effect that theoretically would be produced by an actual recharge well if the aquifer were of infinite extent. This is very important, for the indicated (Fig. 3) departure from the type curve therefore represents an effect directly *opposite* to that indicated by the observed-data curve (Fig. 2), although both curves depart from the type curve in the same direction. Thus, a departure from the type curve, as shown in Fig. 3, does not mean a decrease in the rate of drawdown, but a decrease in the rate of buildup. The reduction in buildup is the effect of a second boundary (barrier type), which may be described by an imaginary discharge image well opposite to, and operating at the same rate and for the same period as, the pumped well.

The deviations of the first departure curve from the type curve are computed and plotted against corresponding values of r^2/t as a second departure curve, which is then matched to the type curve (Fig. 4). Inasmuch as the plotted deviations, or departures, are related principally to a discharging image well, the second departure curve once more represents drawdown. Therefore, a deflection from the type curve, as shown in Fig. 4, indicates another reduction in the rate of drawdown and is to be interpreted as the result of a third image well, which recharges. Once again, the deviations shown in Fig. 4 are computed and plotted against corresponding values of r^2/t; this third departure curve is matched to the type curve (Fig. 5). This time the departure and type curves coincide, indicating that no other image wells are present.

As mentioned above, the image well theory makes it possible to treat

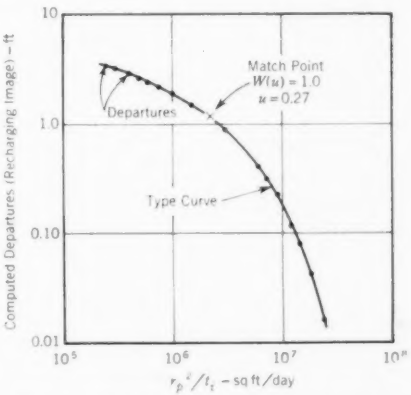

Fig. 5. Match of the Third-Department Curve to the Theis Type Curve

Coincidence of the departure and type curves indicates that no other image well is present.

a problem involving actual boundary conditions like one of a multiple-well system in an infinite aquifer. Therefore, the values derived for the hydraulic characteristics of the aquifer are the same whether computed from the departure curves or the observed-data curve. For a given magnitude of gpd/ft and 1×10^{-4}, respectively, are computed by substituting match-point data in Eq 1 and 2.

It is a common practice among hydrologists to replot departures on the same graph sheet with the observed-data curve. This practice may cause considerable confusion and result in

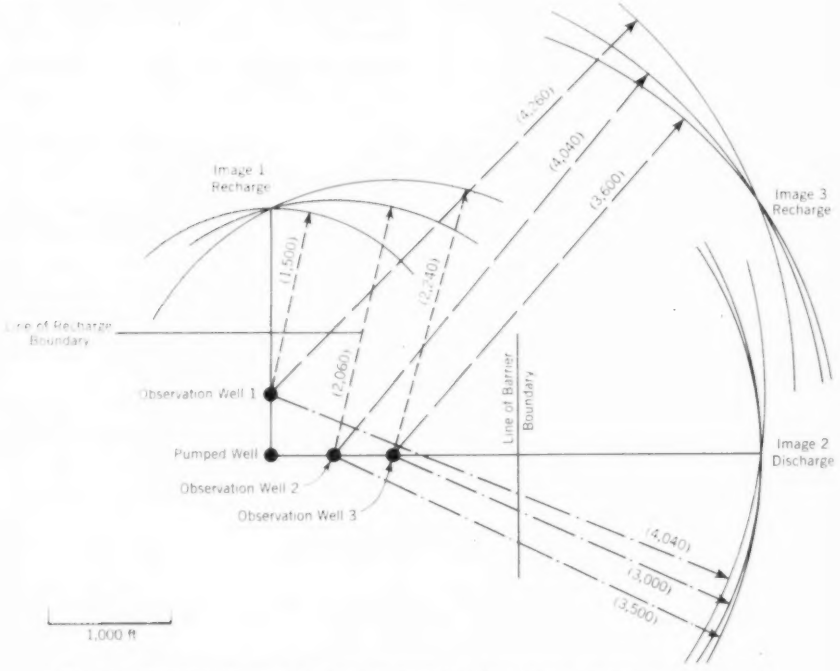

Fig. 6. Construction of Arcs to Determine Locations of Image Wells and Impervious Boundaries

Image well distances are given in parentheses.

drawdown—or buildup, depending upon the type of image well—all data curves match in the same position on the type curve. Therefore, the job of matching the departure curves to the type curve is greatly simplified. The values for the coefficients of transmissibility and storage, which are 100,000

incorrect interpretation unless the character of the replotted departure data is kept clearly in mind. If, as in the example used here, a recharge boundary were involved, then departure data representing buildup in water level would be plotted on the same graph on which one coordinate scale is al-

ready labeled "drawdown." It is therefore recommended that each departure curve be plotted as a separate graph and that the appropriate coordinate scale on each departure graph be labeled according to the type of image well involved (see Fig. 3–5).

The hypothetical test used for illustrative purposes involves both a boundary of the recharge type and one of the impermeable-barrier type. Had a test setup in which a well field is situated between parallel streams been considered, the purposes of this discussion would have been served equally well. A setup between parallel streams would involve an alternating infinite series of recharging and discharging image wells. The latter part of the observed-data curve for such a test would exhibit a decreasing rate of drawdown indicating the nearest recharge boundary. The first departure curve, however, indicating the second recharge boundary, would lie above the type curve.

For a discharging-well type of aquifer test, the interpretations of the logarithmic data plots (s with respect to either r^2/t or $1/t$), when matched to the type curve, may be summarized:

1. For the observed-data curve, an increase in the rate of drawdown signifies a discharging image; a decrease in the rate of drawdown signifies recharging image.

2. For any succeeding departure curve, if the preceding image well is recharging, deviation of the departure curve from the type curve in a manner showing an increasing rate of buildup indicates a new recharging image; deviation showing decreasing rate of buildup indicates a new discharging image. If the preceding image well is discharging, the interpretation is the same as for the observed-data curve.

Location of Image Wells and Boundaries

In the hypothetical test considered thus far, the positions of the image wells and boundaries were known beforehand (Fig. 1). In the evaluation of an actual field test, however, the positions may be approximated from the analysis of the observed-data and departure curves. The distance from the observation well to an image well may be determined from the following formula [6]:

$$r_i = r_p \sqrt{\frac{t_i}{t_p}} \quad \ldots\ldots\ldots (3)$$

where r_p is the distance between the observation well and pumped well, r_i is the distance between the observation well and image well, t_p is the elapsed time for a given magnitude of drawdown produced by the pumped well to be observed in the observation well, and t_i is the elapsed time for the image well to produce the same drawdown in the observation well as that produced by the pumped well at t_p. This formula indicates that, at a given observation well, the times of occurrence of equal drawdown components vary directly as the squares of the distances from the observation well to the pumped well and to its image.

Referring to Fig. 2–5, the observed drawdowns and computed departures are plotted against values of r_p^2/t_p and r_p^2/t_i. Therefore, Eq 3 can be made more useful if it is rewritten as

$$r_i = r_p \sqrt{\frac{r_p^2/t_p}{r_p^2/t_i}} \quad \ldots\ldots\ldots (4)$$

The use of Eq 4 can be readily illustrated by reference to the match point data in Fig. 2–5. The magnitudes of drawdown and departures are the same for all match points. The distance of

TABLE 2

Distances From Observation Wells to Pumped and Image Wells

From Observation Well No.	Distance—ft			
	To Pumped Well	To Image Well 1	To Image Well 2	To Image Well 3
1	500	1,500	4,040	4,260
2	500	2,060	3,500	4,040
3	1,000	2,240	3,000	3,600

the first image well is determined from the observed-data curve and the first departure curve; the distance of the second from the observed-data curve and the second departure curve; and the third from the observed-data curve and third departure curve. From the observed-data curve, it is known that $r_p^2/t_p = 1.42 \times 10^8$; from the first-departure curve, $r_p^2/t_i = 8.35 \times 10^6$; from the second departure curve, $r_p^2/t_i = 2.9 \times 10^6$, and from the third departure curve, $r_p^2/t_i = 2.18 \times 10^6$. The distances from Observation Well 2 to the three image wells are, therefore,

$$r_i = 500\sqrt{\frac{1.42 \times 10^8}{8.35 \times 10^6}} = 2{,}060 \text{ ft}$$

for the first image well,

$$r_i = 500\sqrt{\frac{1.42 \times 10^8}{2.9 \times 10^6}} = 3{,}500 \text{ ft}$$

for the second, and

$$r_i = 500\sqrt{\frac{1.42 \times 10^8}{2.2 \times 10^6}} = 4{,}040 \text{ ft}$$

for the third.

A similar analysis of observed-data and departure curves for Observation Wells 1 and 3 permits the determination of distances between the image wells and the respective observation wells. These well distances are shown in Table 2.

After the image well distances have been determined, arcs are drawn at the computed distances from the observation wells for each image well, using the observation wells as centers. The point of intersection of the arcs for each image locates the image. A point on the aquifer boundary is then the midpoint of the line connecting the image and pumped well (Fig. 6).

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Advancements in Steel Storage Facilities

James O. Jackson

A paper presented on Oct. 19, 1959, at the joint meeting of the Alabama-Mississippi and Southwest Sections, New Orleans, La., by James O. Jackson, Pres., Eng. Development Co., Coraopolis, Pa.

STORAGE facilities are an essential part of the equipment of a water supply system. Although it is possible to pump water from a source, through a treatment plant, and into distribution lines, it is uneconomical to do so, for the capacity of each piece of equipment used would have to be large enough to accommodate the momentary peak requirements of the system. Storage aids in the smooth and economical operation of a system by providing a basis for control and by reducing the needed capacities of equipment.

Uses of Storage Tanks

The many uses for storage tanks in water systems include the storage of raw water and the storage of treated water at the treatment plant or out in the distribution grid, where the stored volume makes possible the economies previously mentioned. In addition, storage tanks are used to improve pressures and flows in the distribution network during periods of high demand by providing high-pressure sources at remote locations in the distribution grid. The small system may be entirely regulated by using the variation in water level of the storage tank to start and stop the pumps feeding the system. In larger systems containing several tanks, top water levels of which are at various elevations, the tank levels may be controlled by altitude valves to accomplish the desired distribution of stored water over the distribution grid and still allow for controlling the operation of the main pumps. Other uses of storage tanks are for wash water storage, ground storage ahead of fire pumps, and storage over fire sprinkler systems.

Storage Volume

Economical storage volume depends on many factors and may be quite different for various systems. The variables that should be evaluated to determine the storage volume needed are:

1. The desirable volume and pressure range to be held in reserve for fire-fighting purposes
2. The desirable volume to be accumulated during off-peak hours, usually from about 8 PM to 6 AM, to reduce the peak treatment and pumping requirements to at least an average daily value
3. The minimum volume and pressure range to provide satisfactory pressures in critical portions of the distribution grid.

Ground storage in natural or artificial lakes is of primary importance. Such storage may have a capacity approaching the total seasonal water requirements of a system.

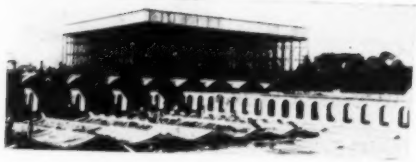


Fig. 1. Elevated Reservoir at Tallah, India

Built in 1911, this all-riveted steel, 11.25-mil gal tank is still in use.

Types of Tanks

Steel tanks for distribution storage may be at ground level or elevated. The former are generally cylindrical and have flat bottoms (hence, they are commonly called "flat-bottom tanks" to distinguish them from the elevated type, which does not have this feature). A ground level tank whose height is equal to or less than its diameter is a "reservoir"; if the height is greater, it is a "standpipe." Elevated tanks may be of different shapes, but all have the characteristic that the larger part of the stored volume is elevated above the ground, so as to provide a tower range of head for all the stored water.

Both flat-bottom and elevated tanks may be made of various materials. Satisfactory tanks have been constructed of masonry, wood, concrete, and steel. Most storage tanks are either cylindrical in shape or composed entirely of curved surfaces, in which the stored water creates tensile or bursting stresses. Tanks built of wood are reinforced by steel bands to resist the bursting stress of the stored water. Tanks built of concrete are reinforced by steel cast in the concrete or by steel wire or rods pre-tensioned on the exterior of the concrete wall. Tanks made of steel plate walls have the inherent strength to resist bursting stresses.

The first steel or wrought-iron tanks used for water supply purposes in the United States were built during the latter half of the nineteenth century and were generally of riveted construction, the seams being calked to make them watertight. Butt-riveted joints with interior and exterior butt straps, having joint efficiencies of more than 90 per cent of the strength of the tank plate, were used on large and important structures. The weight and cost of the butt straps and the many lines of rivets were an appreciable part of the total cost of the tanks.

That the early riveted tanks were not necessarily small structures is illustrated in Fig. 1, which shows an elevated steel reservoir at Tallah, India, used by the Calcutta Water Works. The tank is a rectangular structure, 320 ft square, 16 ft high, with a capacity of 11.25 mil gal. It was built in 1911, of all-riveted construction. The height from the ground to the tank bottom is 110 ft. The total weight of steel in the tank and supports is 4,480 tons. The structure is still in use, and, from all indications, will be for many years.

Flat-bottom tanks. Where natural elevations are available for the location

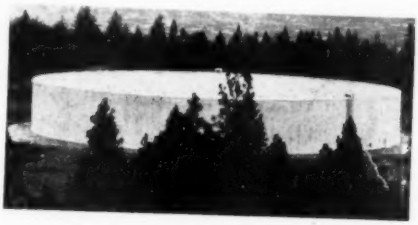


Fig. 2. Reservoir at Spokane

This 10-mil gal steel tank is 240 ft in diameter and 32 ft high.

of a storage reservoir, a flat-botttom steel reservoir, such as that built in Spokane, Wash. (Fig. 2), may be very economical. This 10-mil gal reservoir has a diameter of 240 ft and a height of 32 ft. The cost of the water lines to the tank location and the cost of pumping against the friction of the lines may be factors that would indicate greater economy in one or more elevated tanks located in, or near, the distribution network.

The tanks shown in Fig. 3 have water-containing elliptical roofs. This tank with a diameter of 116 ft and a head range of 95 ft, and in Doraville, Ga., which has a 5-mil gal, 133-ft diameter tank.

Other types of flat-bottom tanks are shown in Fig. 4. The standpipe at Livingston, N.J., has an umbrella-type roof, which may be economically constructed of flat steel plates. The roof of the reservoir at Ottumwa, Iowa, and the roof of the standpipe at Clearwater, Fla., are supported by external ribs, which also have an ornamental appearance.

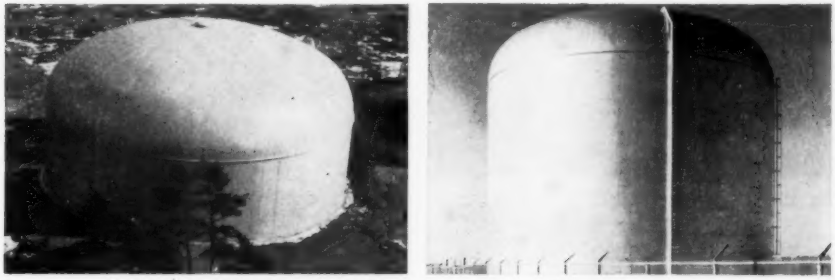


Fig. 3. Reservoirs With Water-Containing Elliptical Roofs

The 4-mil gal tank on the left, built in Bangor, Me., has a 120-ft diameter and a 48-ft head range. The photograph on the right shows a 5-mil gal tank, 100 ft in diameter and 85 ft to the bottom, built in Philadelphia.

construction is often economical, as the roof may be used to contain water and to serve as a weather closure as well. The choice of the height of steel reservoirs depends not only on the location of the tank but also on the permissible pressure variation. In some localities it is desirable to have the large extra volume in the lower part of the tank, even at a lower pressure. Such volume may provide an economical reserve storage to feed fire pumps or be used as a reserve supply. Other elliptical-roof reservoirs are in Mifflin Township, Pa., which has a 7-mil gal

Elevated tanks. Elevated tanks are practical for storing a desired quantity of water within low limits of head or pressure variation at any location. In flat terrain, it is usually economical to provide the desired volume within the allowed pressure variation in elevated tanks. In the early elevated tanks, the capacities were usually 50,000–100,000 gal to meet the fire reserve requirements of small towns. The tanks were cylindrical in shape, first with flat, then with hemispherical, bottoms, and usually with cone roofs. The average height to the bottom was

about 100 ft. These tanks were so common for towns of small size that they were frequently called "tank towns." As the size of the communities increased, with corresponding increases in the water requirements and in the size and complication of the distribution networks, elevated tanks of larger capacity were often the most economical means of providing the desired volume and pressure throughout the system.

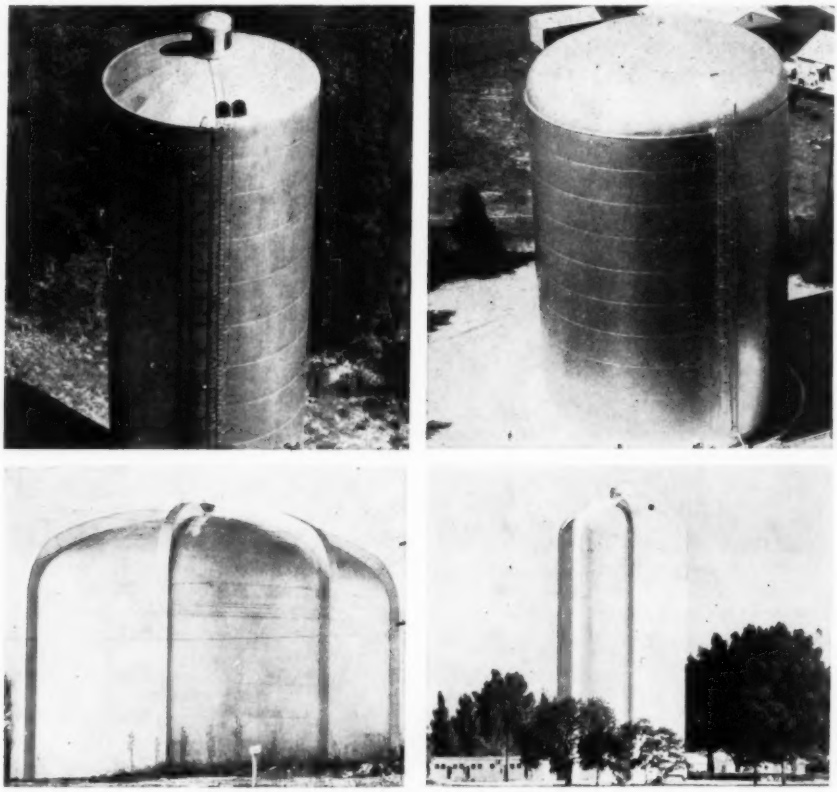


Fig. 4. Varieties of Flat-Bottom Tanks

Upper left: Standpipe at Livingston, N.J., 92 ft high, 34 ft in diameter, with umbrella-type roof. Upper right: Standpipe at Phoenixville, Pa., 80 ft high, 34 ft in diameter, with ellipsoidal roof. Lower left: 4.2-mil gal reservoir at Ottumwa, Iowa, with a 110-ft diameter and 60-ft head range. Lower right: 1-mil gal standpipe at Clearwater, Fla., 43 ft in diameter and 95 ft to bottom.

Figure 5a shows a typical 50,000-gal hemispherical-bottom elevated tank, 100 ft to bottom, with laced-channel steel columns. Many thousands of

these tanks were built throughout the United States, and many of them are still in use. As larger capacities were required, the hemispherical bottom was replaced by the elliptical bottom, because the latter was more economical in large tanks. The cone roof was replaced by an elliptical water-containing roof for reasons of appearance and economy, and the structural columns were superseded by tubular steel columns because of their better appearance, easier maintenance, and, often, because the number of panels required in the tower was reduced. Figure 5b shows a modern double-ellipsoidal tank, 100 ft to the bottom.

The double-ellipsoidal tank, although very economical for small capacities, becomes more costly than other types of tanks when the capacity is greater than 500,000 gal. The need for developing economical tanks of large capacity has resulted in several ingenious designs. Figure 5c shows a 1-mil gal radial-cone elevated tank, built for the city of Montgomery, Ala. In this design, the thickness and cost of the bottom plates are greatly reduced by fabricating them so that they bulge outward between radial girders, thus reducing the stresses considerably. This type of tank may be built economically in very large capacities and small ranges of head. A variation of the radial-cone design, in which the tank shape is obloidal and the radial girders extend around the tank to form supporting ribs for the roof, is shown in Fig. 5d.

Another type of large tank bottom, which economically provides for a low range of head in large tanks, is the toroidal bottom. In this design, a portion of a toroidal shell forms the exterior part of the bottom; the center part is closed either by a spherical segmental portion or by a conical extension of the riser pipe. Figure 5e shows a 1-mil gal torospherical tank, built for the US Army Corps of Engineers at White Sands, N.M.

A torosegmental tank is shown in Fig. 5f. In this design, the inner edge of the toroid and the outer edge of the spherical segment are supported by an inner row of tubular steel columns. The toroidal design is also suitable for tanks of medium capacity.

For elevated tanks of small and medium capacity, the four-post, hemispherical-bottom tank has been superseded by the single tubular-column pedestal tank, which is usually spherical in shape and which provides a structure having an attractive appearance and a minimum of smooth surface to maintain. Single-pedestal tanks have recently been constructed with a spheroidal or double-elliptical shape, having a larger capacity than the spherical shape (Fig. 6).

Advantages of Steel

Steel has proved to be an ideal material for storage tanks because:

1. Steel can resist indefinitely the loads and stresses caused by the weight and pressure of stored water.

2. The type of steel specified by AWWA for use in tanks is soft and ductile, very suitable for welding, and remains tough, ductile, and shock resistant at minimum storage temperatures.

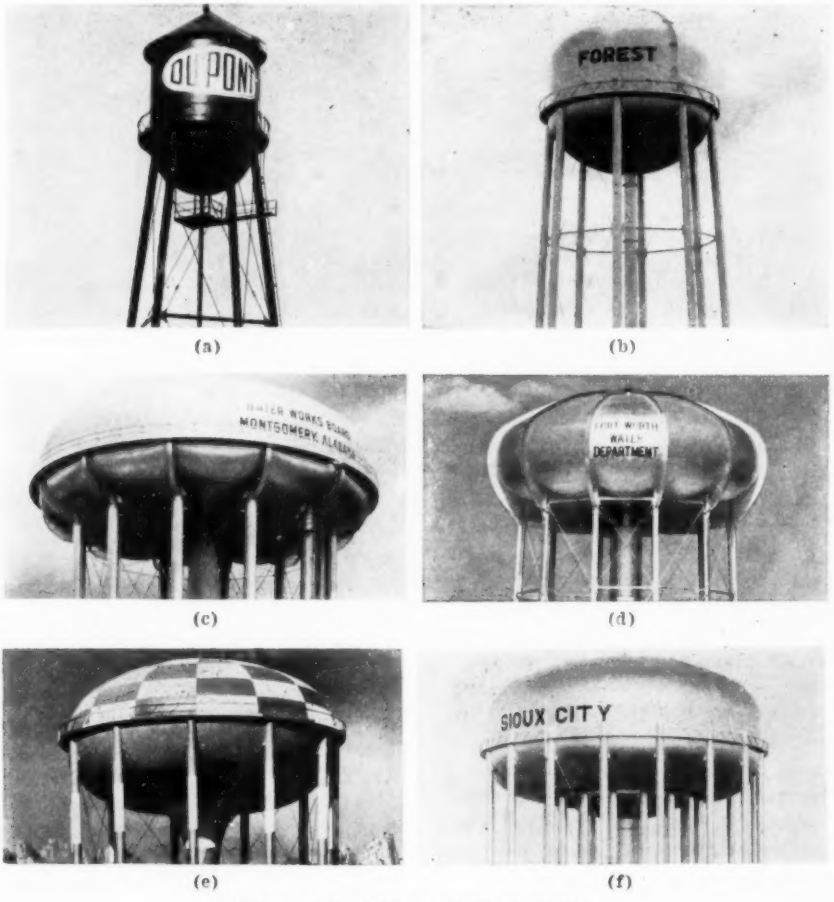
3. Steel plates may be shop formed into the double-curved surfaces required by economical tank design and field welded into a monolithic structure in which there is no interaction between composite materials.

4. Many of the steel tanks built just before the turn of the century

are still in use and will give service as long as they are given adequate maintenance.

5. Steel tanks may be economically maintained to present a pleasing appearance and, by the application of protective paints, to protect surfaces from corrosion.

6. Techniques of cleaning and protecting steel surfaces have so advanced



(a) (b) (c) (d) (e) (f)

Fig. 5. Varieties of Elevated Tanks

The types of tanks shown are: (a) 50,000-gal hemispherical-bottom tank; (b) 500,000-gal double-ellipsoidal tank, with 50-ft diameter and 39-ft head range, at Forest, Miss.; (c) 1-mil gal radial cone, 106 ft to bottom and 25-ft head range, at Montgomery, Ala.; (d) 1-mil gal obloidal tank, with 88-ft diameter, 25-ft head range, 88 ft to bottom, at Fort Worth, Tex.; (e) 1-mil gal torospherical tank, with 80-ft diameter, 35-ft head range, 99 ft to bottom, at White Sands, N.M.; and (f) 2-mil gal torosegmental tank, with 102-ft diameter, 35-ft head range, 70 ft to bottom, at Sioux City, Iowa.

in the past decade that suitable paint coats on both the interiors and exteriors of water tanks will last at least 5 years.

7. Steel tanks have a high scrap value and, therefore, can be sold when they are no longer serviceable.

8. Welded steel tanks can be readily taken down and re-erected at another location, at a cost considerably lower than that of building a new tank.

9. Steel tanks have the ability to resist wind and earthquake loads much greater than those for which they were designed. Many elevated steel tanks have been only slightly damaged by hurricanes, tornadoes, and earthquakes that have demolished most nearby structures.

10. Repeated expansion and contraction have no harmful effect on steel tanks.

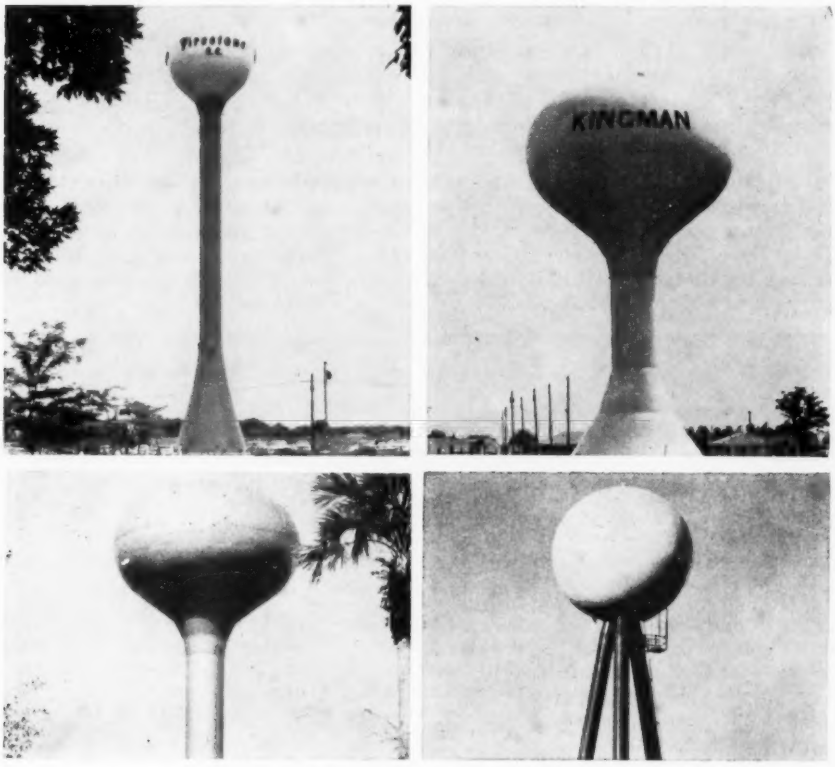


Fig. 6. Varieties of Spheroidal Tanks

Upper left: 50,000-gal tank, 100 ft to bottom, built for the Akron, Ohio, country club of the Firestone Tire & Rubber Co. Upper right: 500,000-gal tank, 56 ft in diameter, on a pedestal elevating it 61 ft to bottom, built for the city of Kingman, Kan. Lower left: 500,000-gal tank, 125 ft to bottom, 30-ft head range, at Orlando, Fla. Lower right: 100,000-gal spherical tank, with 31-ft diameter, 23-ft head range, elevated on a tripod 100 ft to bottom, at Gonzales, Calif.

11. Steel tanks are permanently watertight and nonabsorptive. Water exposure cannot cause steel tanks to leak, chip, or spall.

Conclusion

Welded steel tanks can be constructed in a variety of economical designs to meet a variety of requirements. They may be accurately designed to withstand the loads and stresses imposed on them. They may be economically fabricated and quickly field welded to produce leakproof structures of known strength, having a pleasing appearance and an economical service life.

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Use of Prestressed Concrete for Storage Facilities

John J. Closner

A paper presented on Oct. 19, 1959, at the joint meeting of the Alabama-Mississippi and Southwest Section, New Orleans, La., by John L. Closner, Pres., The Preload Co., New York, N.Y.

WATER storage is a big business, representing a large part of the multibillion-dollar investment in water supply systems. Storage tanks being built today are generally either of reinforced concrete (prestressed or not prestressed) or of steel. The use of each type has advantages and disadvantages. Concrete has long and successfully been used constructing settling tanks, filters, clear wells, and pipelines.

Prestressed concrete is concrete reinforced so that it can function under tension. Prestressing is based on the principle of applying to a concrete wall an external pressure that is always greater than the internal pressure, thus preventing the concrete from cracking. This principle is not new, nor are the methods of prestressing in general use today new. They have been successfully used on approximately 2,000 tanks built throughout the world over a period of 30 years.

Applications

The first applications of prestressing, using medium-strength rods, occurred in the 1920's. Since then, many prestressed concrete tanks have been constructed for ground storage, elevated storage, and treatment facilities. A 50-ft ID, 100-ft high standpipe, built in 1936 in New Britain, Conn. (Fig. 1), has required no maintenance after more than 20 years of use.

The 2-mil gal elevated tank shown in Fig. 2 was constructed in Tyler, Tex., several years ago. It is 100 ft in diameter, 35 ft high, and rests on a tower 160 ft high.

A 5-mil gal tank, built in Marrero, La., has an interesting feature of construction. Use was made of precast segments for the 150-ft diameter, spherical dome roof. Figure 3 shows the roof being installed.

Prestressed concrete is being used for larger and larger tanks. Several years ago, two 13-mil gal reservoirs, 292 ft in diameter, were constructed for the city of Reading, Pa. (Fig. 4). Now under construction in Springfield, Mass., are two 15.5-mil gal reservoirs, 320 ft in diameter. Designs have been completed for the construction, in Dallas, of a reservoir with a capacity of 22 mil gal. It will be 350 ft in diameter. It can thus be seen that there are many practical applications of prestressed concrete for water storage.

Design Considerations

There is no particular mystery surrounding the design of a prestressed concrete tank, but special procedures

Fig. 1. Standpipe in New Britain, Conn.

This prestressed concrete standpipe, built in 1936, is 100 ft high, with a diameter of 50 ft.

have been developed with respect to design and construction, not only of the prestressed concrete wall but also of the footings, floors, and roofs. Particularly for footings and floors—which are of reinforced concrete and, in general, follow accepted designs—special attention should be given to the reinforcing requirements to control cracking due to shrinkage and temperature. The standards of the author's company require that tank floors have a minimum of 0.5 per cent reinforcement in each direction and that the circumferential steel in the wall footing have a similar reinforcement for footings of normal dimensions. The roofs of prestressed concrete tanks may be domed or flat slab, or beam and slab, or precast.

The prestressed wall is a cylindrical shell with edge restraint, the design of which is set forth in such texts as Timoshenko's *Theory of Plates and Shells*.[1] Experience indicates that, in the wall, a minimum of 0.5 per cent mild steel vertical reinforcement should be provided to allow for temperature and shrinkage. It has been found that the warping effect due to excessive drying of the exterior surface, as opposed to the wet interior surface, and temperature differentials create potentially troublesome stresses. These must be recognized and proper reinforcement provided.

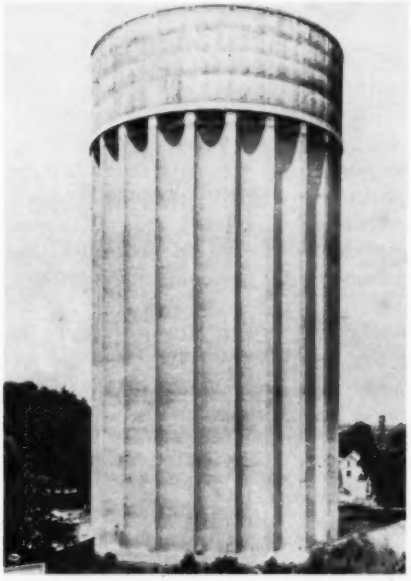

Fig. 2. Elevated Tank in Tyler, Tex.

This prestressed concrete tank is 100 ft in diameter, 35 ft high, and rests on a tower 160 ft high.

Bending moments in the wall due to edge restraint can be substantially reduced by floating the wall on rubber pads (Fig. 5), thus permitting it to move inward when prestressed. The joint between the footing and wall is sealed watertight with a dumbbell waterstop. Other types of base joints may be used, including sliding, hinged, or fixed joints, but the greater bending moments will require additional wall concrete and reinforcement. Circumferential prestressing of the tank base shown in Fig. 5 was done by winding it with wire applied at a stress of 150,000 psi.

Construction

With all the fine conceptions of design, it still requires sound construction to produce a good tank. Proper workmanship, materials installed in accordance with plans and specifications, and adequate inspection will insure many years of trouble-free service.

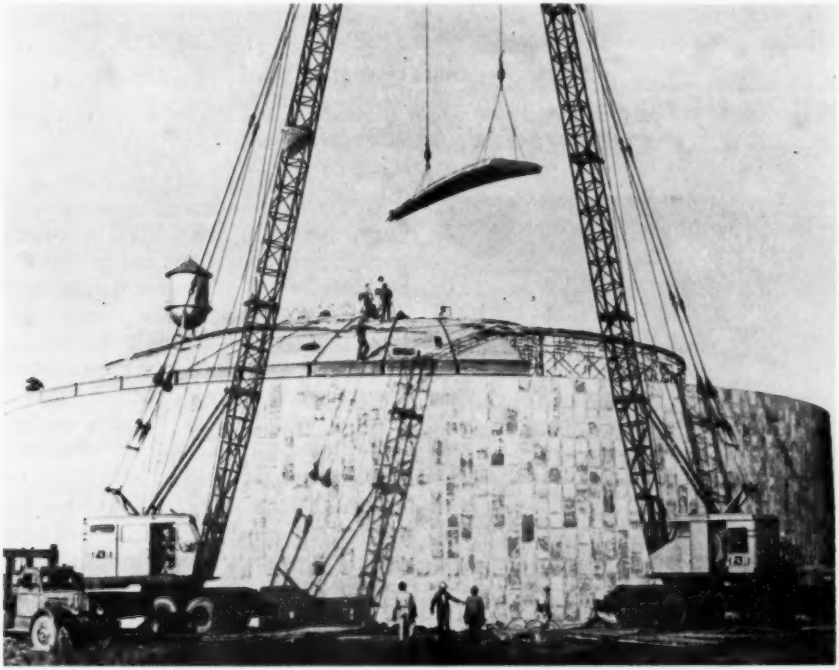

Fig. 3. Storage Tank in Marrero, La.

The 150-ft diameter spherical dome roof of this 5-mil gal prestressed concrete tank was installed with precast sections, as shown.

The necessity for adherence to plans and specifications cannot be emphasized too strongly. No better concrete work is required for prestressed concrete than for reinforced concrete. Cold joints, unspecified construction joints in the wrong place, incorrect placement or alignment of steel, improperly placed,

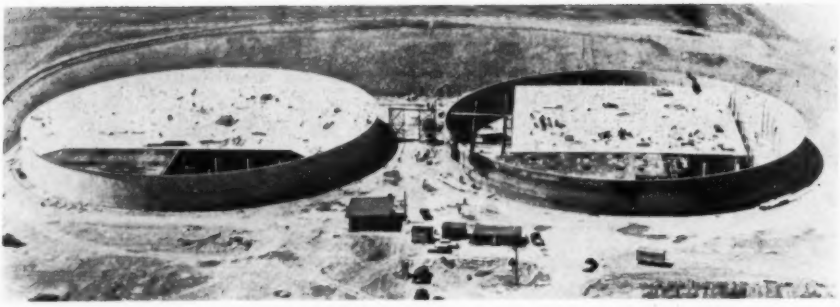

Fig. 4. Reservoirs in Reading, Pa.

These two 13-mil gal reservoirs, each 292 ft in diameter, are examples of the use of prestressed concrete for large water facilities.

Fig. 5. Elimination of Bending Moments in Reservoir Wall

In the base of this reservoir, shown in Fig. 4, the wall was made to float on rubber pads to reduce substantially the bending moments due to edge restraint.

consolidated, and cured concrete will cause defects in tanks. All specifications for concrete construction include adequate requirements for curing, and yet these requirements are probably the least observed of all, in spite of the fact that curing is one of the simplest phases of concrete construction. When work of less than the specified quality is accepted, the completed structure may leak or have other defects. The blame may then be attributed to the prestressed concrete tank, when the fault really lies in the permitting and accepting of improper methods of construction.

Economic Considerations

Economic considerations of water supply facilities should be based on total or ultimate cost, not on initial cost. Total costs are affected by out-of-service time, cleaning and painting, and the impact of inflation on future expenditures. Local labor and materials for the construction of a prestressed concrete tank can be used where desirable as well as economically justifiable.

Summary

1. Prestressed concrete is only an extension or improvement of reinforced concrete.

2. All types of water storage or treatment facilities can be built of prestressed concrete.

3. Construction with prestressed reinforced concrete is no more of a problem than construction with unprestressed reinforced concrete, but it does require the same attention to inspection and adherence to specifications. Specialized work that a general contractor would not normally do can be handled by companies experienced in working with prestressed concrete, just as a subcontractor would handle work with reinforcing steel.

4. When consideration is given to costs of a storage facility, the most important is the ultimate or total cost to the owner.

Reference

1. TIMOSHENKO, S. *Theory of Plates and Shells.* McGraw-Hill Book Co., New York (1940).

Municipal Water Consumption in the United States and Europe

In spite of some diversity in dates, the table presented below gives a good general comparison of water consumption in various cities in Europe and the United States. This table has been prepared from data compiled and supplied by Wilfred Christensen, Copenhagen, Denmark, and from USPHS figures. Production data were not available for European cities.

City	Year	Production *gpcd*	Consumption *gpcd*	City	Year	Production *gpcd*	Consumption *gpcd*
Amsterdam	1957		41	New York	1955	136	*
Boston	1955	160	153	Paris	1954		82
Chicago	1955	234	*	Philadelphia	1955	177	175
Dallas	1955	150	125	Pittsburgh	1955	146	107
Detroit	1955	155	137	St. Paul	1955	115	96
Gothenburg	1957		69	San Francisco	1955	108	94
Helsinki	1952		59	Seattle	1955	132	121
London	1952		59	Stockholm	1957		86
Los Angeles	1955	177	161	Vienna	1949		59
Miami	1955	148	136	Washington D.C.	1955	151	138
New Orleans	1955	177	161	Zurich	1957		88

* Consumption not metered.

Distribution of Soil Conductivity and Its Relation to Underground Corrosion

Gordon N. Scott

A paper presented on Jul. 16, 1959, at the Annual Conference, San Francisco, Calif., by Gordon N. Scott, Cons. Engr., Los Angeles, Calif.

UNDERGROUND corrosion of pipelines is related to soil conductivity. In a previous article [1] it was shown empirically that a set of random soil resistivity measurements plotted on logarithmic probability paper was likely to fall on a straight line. The area, or linear extent of soil, over which resistivity measurements thus conformed was said to be statistically uniform.

In a later article [2] it was shown that, in a statistically uniform soil, a relation exists between corrosion of pipelines and soil resistivity, or its reciprocal, conductivity. The form of the relationship is not indicated by statistical analysis, but may be deduced by expanding Ohm's law in the light of the electrochemical theory of corrosion.

It is axiomatic that the underground environment in which a pipeline is to be laid should be explored. But methods of analyzing soil resistivity data to encourage better engineering in underground corrosion are available.

Logarithmically Normal Distribution

Mathematical statistics holds a wealth of unexploited analytical power for scientists and engineers in practically all fields in which observations are essentially quantitative. One of the more familiar uses of statistical methods is in quality control, where some characteristic of a manufactured product must not vary from a specified norm by more than a fixed amount. Lack of conformity within specified limits serves as a basis for rejection of a unit or lot. This profitable application and the preparation of common charts, showing variations in commodity prices, weather, and the like, constituted the usual concept of statistics. But beyond these more common uses statistics is a powerful analytical tool, and it can be applied to underground corrosion with much profit.

Statistical theory provides a simple method of portraying soil resistivity data as a probability distribution. If the resulting curve is a straight line on suitable coordinates, the distribution may in some instances be uniquely described by two parameters: the mean, which indicates the central tendency of the data, and the standard deviation, which measures the scattering of the measurements.

There are two functions of particular interest in statistical distributions. One is the probability density function $f(x)$ which is such that $f(x)\ dx$ gives the relative frequency of the variate x in the interval dx. The other is the cumulative probability $F(x)$

which is the integral of the probability density $f(x)$ from $-\infty$ to x. The probability density is defined so that the integral over the entire range of the variate is equal to unity. With this condition the cumulative probability will fix on a scale from 0 to 1 the chances that the variate will be less than or greater than any value of x—that is, that it will fall within a chosen range. The problem may be stated more formally as follows:

$$F(x) = \int_{-\infty}^{x} f(x)\,dx$$

when

$$\int_{-\infty}^{+\infty} f(x)\,dx = 1 \quad \ldots\ldots\ldots (1)$$

The equations state that if the integral of $f(x)$ over all possible values of x $(-\infty < x < +\infty)$ is equal to one, then $f(x)$ is a probability density and the cumulative probability $F(x)$ will be the integral over that range of the density function from its least value to the value x.

If the probability density of a variate t is of the form

$$f(t) = (2\pi)^{-\frac{1}{2}} \exp(-t^2/2) \quad \ldots\ldots (2)$$

the distribution of t is said to be normal. As $f(t)$ is a density function, it follows that the integral over the entire range of t equals one. The curve of the density $f(t)$ as ordinate and the variate t as abscissa, is symmetrical about the value $t = 0$, where the density is a maximum. The curve approaches the t axis asymptotically as t becomes increasingly large or small. The shape of the curve has often been likened to the cross section of a bell. If one makes the arbitrary transformation

$$x = \mu + \sigma t \quad \ldots\ldots\ldots (3)$$

then the probability density equation becomes

$$f(x) = (2\pi\sigma^2)^{-\frac{1}{2}} \exp -\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2 \quad \ldots (4)$$

If the parameter σ is set equal to one for the moment, it is clear that the effect of a change in μ is simply to move the axis of symmetry of the bell-shaped, probability-density curve to the right or the left along the x-axis. At fixed μ the effect of a change in σ is to flatten or steepen the curve. The parameters μ and σ are, obviously, the mean and the standard deviation of the normal distribution.

TABLE 1

Ordered Soil Resistivities and Estimated Cumulative Probabilities*

Rank (m)	Resistivity *ohm-cm*	Logarithm of Resistivity ξ ($\log \rho$)	Field Test No.	Estimated Cumulative Probability (P)	Reduced Variate (t)
1	590	2.77085	9	0.0625	−1.534
2	910	2.95904	13	0.1250	−1.150
3	960	2.98227	3	0.1875	−0.887
4	980	2.99123	12	0.2500	−0.675
5	1020	3.00860	6	0.3125	−0.488
6	1070	3.02938	8	0.3750	−0.319
7	1100	3.04139	10	0.4375	−0.157
8	1260	3.10037	5	0.5000	0.000
9	1470	3.16732	7	0.5625	0.157
10	1620	3.20952	2	0.6250	0.319
11	1700	3.23045	11	0.6875	0.488
12	1760	3.24551	4	0.7500	0.675
13	2000	3.30103	14	0.8125	0.887
14	2300	3.36173	15	0.8750	1.150
15	2700	3.42136	1	0.9375	1.534

* Southern California Edison Co.; Etiwanda fuel supply line. Tests of May 1956 between Santa Fe Springs and Tonner Pump Stations.

All normal distributions characterized by the two parameters may be reduced to the standard form of Eq 2. This happy circumstance permits preparation of single tables of the probability density function and the cumulative probability integral.

If one makes the further transformation $x = \log \rho$, then, from Eq 3,

$$\log \rho = \mu' + \sigma' t \quad \ldots\ldots\ldots (5)$$

in which $\mu' = \log \mu$ and $\sigma' = \log \sigma$. This notation conflicts with convention, but there will be no confusion if it is understood that μ and σ are the antilogarithms of the mean and of the standard deviation, respectively, of the normally distributed log ρ. Although they are related, the mean and the standard deviation of the skew distribution of ρ are not the antilogarithms of μ and σ as these symbols are used here.

The distinction will be clarified by showing the relations between these several quantities. By definition, the mean (average) of a set of measurements is their sum divided by the sample size (the number of measurements) —that is,

$$\mu = \frac{1}{n} \sum_{i=1}^{n} \rho_i = \frac{1}{n} (\rho_1 + \rho_2 + \cdots + \rho_n) \quad \ldots (6)$$

Applying this definition to find the mean of log ρ, one finds

$$\mu' = \frac{1}{n} (\log \rho_1 + \log \rho_2 + \cdots + \log \rho_n)$$

$$= \log (\rho_1 \rho_2 \cdots \rho_n)^{1/n}$$

whence

$$\mu = \log^{-1} \mu' = (\rho_1 \rho_2 \cdots \rho_n)^{1/n} \quad \ldots\ldots (7)$$

Thus the number reported for the mean will be the nth root of the product of all n measurements and not one nth of the sum of all the measurements, as in Eq 6.

Similarly, because

$$\log \rho_t = \log \mu + t \log \sigma$$

$$\sigma = (\rho_t / \mu)^{1/t} \quad \ldots\ldots\ldots (8)$$

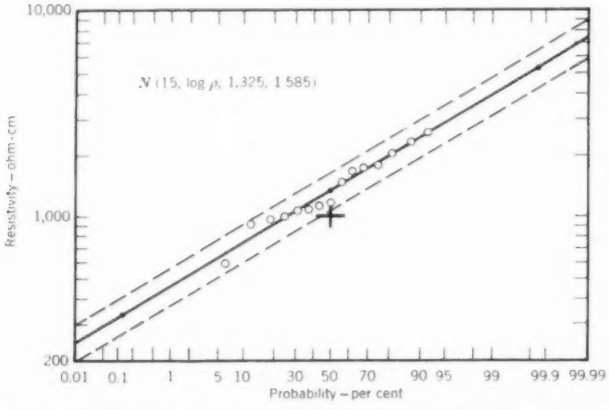

Fig. 1. Soil Resistivity Measurements Plotted on Logarithmic Probability Paper

The fifteen measurements, falling well within the calculated control limits (dashed lines), confirm the hypothesis that the resistivities are logarithmically normally distributed and permit characterization of the soil area as statistically uniform.

Thus the number reported for the standard deviation of a set of soil resistivities whose logarithms are normally distributed will be the ratio of the resistivity at one integral standard deviation ($t = 3, 2, 1, 0, -1, -2, -3$) to the resistivity at the next adjacent smaller integral standard deviation.

$$\sigma = \rho_{(t+1)} / \rho_t = \rho_1 / \mu = \mu / \rho_{-1}; \ \mu = \rho_0 \quad \ldots (9)$$

This ratio will be called the standard-deviation quotient.

The author must make one additional apology to formal statistics: for simplicity no differentiation is made here between population means and standard deviations and the estimates of these quantities from samples of finite size.

With the soil parameters thus explained, one may represent the logarithmic normal distribution of a finite sample of soil resistivities as: N (n, $\log \rho$; μ, σ). This symbolic representation states that the logarithm of soil resistivity, $\log \rho$, is normally distributed N with the geometric-mean resistivity μ and the standard-deviation quotient σ estimated from n measurements.

Determination of Uniformity

The foregoing ideas may be more readily grasped if one considers a typical distribution of a random set of soil resistivity measurements. In Table 1 are given a series of resistivity measurements, in order of increasing magnitude, taken for the Southern California Edison Co. over a portion of the right-of-way of its Etiwanda fuel supply line. The order in which the fifteen measurements were made is also shown in Table 1. These are the consecutive field-assigned test numbers. The logarithms of the resistivities are also given. The cumulative probability of occurrence of a measurement equal to or less than any one of the measured values is estimated from the rank (ascending order of magnitude) m of that measurement and the total number of measurements n, plus 1. Thus the estimated cumulative probability is

$$P(\rho \leq \rho_m) = m/(n + 1) \ldots\ldots (10)$$

The reason for basing the estimate on a sample size one greater than the number of measurements n is to insure that all measurements will fall on probability paper, which is usually limited to the percentage probability range 0.01–99.99. The probabilities estimated in this way are listed in Table 1. The probability that a resistivity measured at random over the right-of-way will be equal to or less than 980 ohm-cm is estimated to be 0.25, as follows:

$$P(\rho \leq 980) = 4/(15 + 1) = 0.25$$

Thus 25 per cent of any number of random measurements will be equal to or less than a resistivity of 980 ohm-cm. From the table, again, the chances that any soil resistivity measured will be less than 2,700 ohm-cm are 93.75 in 100. This is the best estimate that can be made from the tabulated data, but this estimate, as will be evident later, can be greatly improved upon.

If the estimated probabilities are located in a table of standard normal probabilities, such as is given in many handbooks,[8] the corresponding value of the reduced variate t may be found The values of t corresponding to the estimated probabilities appear in the final column of Table 1.

If the resistivity measurements of Table 1 are plotted on double logarithmic probability paper,* as shown in Fig. 1, one may, by sight or with the aid of a black thread, draw a straight line through the data plots. As can be seen in Fig. 1, a straight line seems to fit the data rather well. Because the curve is a straight line it is concluded that the soil resistivities of Table 1

* Logarithmic Probability Paper No. 328; Codex Book Co., New York, N.Y.

follow a logarithmically normal distribution. It need hardly be mentioned that the probability axis has been stretched in such a way that a normal distribution plots on a straight line.

In elementary publications on statistics[4, 5] methods are given by which a straight line such as the one drawn through the points plotted in Fig. 1 may be more objectively determined. The geometric-mean resistivity of the plotted data from the line thus minimized, can now be drawn.

Although the curve in Fig. 1, which was determined as outlined above, does not differ much from the one that could have been drawn by eye, the essential problem is not whether the most probable curve has been drawn but whether the fifteen points do, in fact, conform to a straight line within the natural or expected fluctuations in the data.

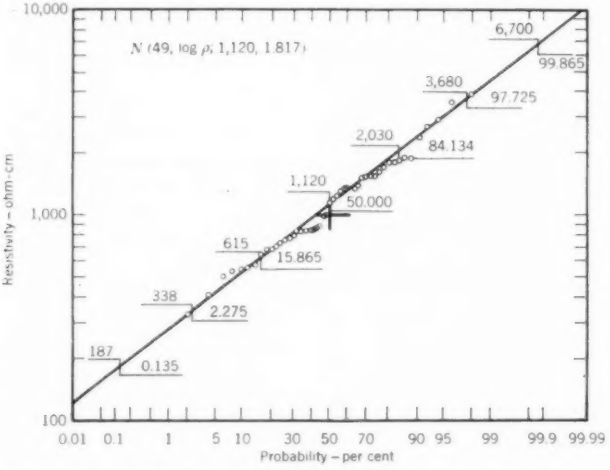

Fig. 2. Estimation of Soil Parameters From a Resistivity Plot

Shown above is a straight line drawn by eye through 49 soil resistivity measurements from a statistically uniform soil. From this line the median (geometric mean resistivity) and the standard-deviation quotient (antilogarithm of the standard deviation of the logarithms of the resistivities) were estimated as shown.

sample is accurately calculated in the procedure and is shown in Fig. 1 as a small black dot at a percentage probability of 50. Values of the variate at, for example, plus or minus three times the logarithmic standard deviation, are also calculated in the procedure. These values are also shown as small black dots to either side of the mean. A straight line, with deviations of the

To answer this question, one can construct bounding curves to serve as a basis for accepting or rejecting the hypothesis that the data conform to a straight line as herein defined. All experimental points in Fig. 1 fall well within the control curves, and it is therefore concluded, with a chance of more than 997 times in 1,000, that the hypothesis is correct, that the data

conform to a straight line on logarithmic normal probability paper.

The assumption that the soil is statistically uniform is in this example indeed acceptable. Had one or more points fallen outside the limiting curves, the assumption that log ρ is normally distributed would have to be rejected unless an errant datum could be rejected because an assignable cause for nonconformity were apparent or could be found. On the other hand, the assumption could still be accepted if a somewhat loosened definition of straightness were accepted. Because they involve logarithms, the calculations for the construction of the bounding curves are exceedingly tedious and cannot therefore be explained or further amplified here. For details the references cited[4, 5] should be consulted. For practical purposes, statistical uniformity need not be justified rigorously.

Even in statistically uniform soils, resistivities often extend through three or four logarithmic cycles. In Fig. 3, for example, the range in resistivity is 9,500–1,000,000 ohm-cm. Because logarithmic probability papers are limited to two logarithmic cycles, the estimated probabilities in such an instance can be converted to the reduced variate t, as was done in Table 1, and can be plotted with associated resistivities on multicycle semilogarithmic paper. Such a graph yields a straight line if the resistivities are logarithmically normally distributed. Similarly, without special-coordinate paper, the logarithms of resistivity in Table 1 may be plotted against associated values of the standardized variate t on ordinary linear-coordinate paper. All plots yield the same values for the soil parameters if the soil resistivities are logarithmically normally distributed.

The graph in Fig. 1 shows that the variate log ρ is normally distributed, and that fifteen measurements were used to determine the mean of 1,325 ohm-cm and the standard-deviation quotient of 1.585. Most corrosion engineers understand the significance of a resistivity of 1,325 ohm-cm, but they might well be confused by a logarithmic mean between 3 and 4, which would correspond to a resistivity between 1,000 ohm-cm and 10,000 ohm-cm.

TABLE 2

Some Properties of the Logarithmic Normal Distribution

Reduced Variate (t)	Probability *per cent*	Soil Resistivity *ohm-cm*	No. of Measurements Between Integral Values of t	Estimated Standard-Deviation Ratio*
−3	0.135	187		
			1	1.818
−2	2.275	338		
			6	1.819
−1	15.865	615		
			18	1.821
0‡	50.000	1120		
			19	1.812
1	84.135	2030		
			4	1.813
2	97.725	3680		
			1	1.821
3	99.865	6700		

* Total number of measurements is 49.
† Average standard-deviation ratio is 1.817.
‡ Mean.

As explained, the symbolic description is not in strict accord with convention,[6] but is used for simplicity and to avoid possible confusion.

Given the soil parameters in Fig. 1, the cumulative probability distribution curve can be readily constructed. The resistivity corresponding to plus or minus one logarithmic standard deviation at the probabilities 84.135 and 15.865 is the mean resistivity of 1,325

ohm-cm at 50 per cent probability multiplied or divided by 1.585, as required by Eq 9. Thus, at plus or minus one standard deviation the resistivities are $1{,}325 \times 1.588 = 2{,}100$ ohm-cm and $1{,}325/1.588 = 836$ ohm-cm. The required curve is a straight line through the three points plotted on logarithmic probability paper. It should be noted that the probability density of resistivity on a nonlogarithmic, or linear, scale is reciprocally symmetrical, in that a product of the soil parameters is involved to one side of the mean and a quotient to the other side.

Parameters of a Uniform Soil

The 49 soil resistivity measurements plotted as a probability distribution in Fig. 2 were taken in 1952 for a water company near Camarillo, Calif. The measurements conform well to a straight line drawn by sight through the data, and the soil area over which the measurements were made is therefore taken to be statistically uniform. One may therefore characterize the soil graphically, as in Fig. 2, to exhibit the number of measurements taken and the soil parameters estimated from the curve. Shown in Fig. 2 are the median, or geometric-mean, resistivity of 1,120 ohm-cm and six values of resistivity and associated probabilities at plus and minus one, two, and three standard deviations. The cumulative probabilities at the integral values of the reduced variate t are those obtained from probability tables. The resistivities are read from the curve at the corresponding cumulative probabilities. The ratio between consecutive resistivity values all yield standard-deviation ratio estimates close to the average of 1.817. The arguments are summarized in Table 2.

It has thus far been shown that soil parameters are quickly obtained from a curve if the soil is statistically uniform. The geometric mean is the value of resistivity at the 50 per cent point on the abscissa. The ratio of interpolated resistivities at integral values of t determines the standard-deviation quotient, the logarithm of which is the standard deviation of the logarithmic normal distribution.

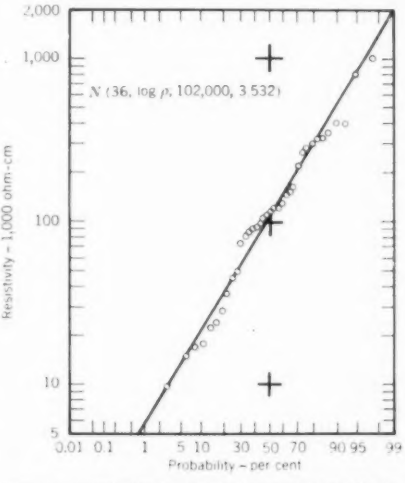

Fig. 3. Resistivity Plot for an Essentially Noncorrosive Soil

As can be seen, the measurements of exceedingly high resistivity are distributed over a wide range.

Another easy method for estimating the standard deviation is to subtract the logarithm of 187 from the logarithm of 6,700 and divide the subtrahend by 6, as there are 6 standard-deviation intervals between these resistivities at ± 3 standard deviations, corresponding to percentage cumulative probabilities of 0.135 and 99.865. The antilogarithm of the result is the

ratio 1.817, which is the sixth root of the ratio, 6,700/187.

From the second column of Table 2, 68.27 per cent (33.5 theoretical against 37 actual) of the measurements will lie within the range from -1 to $+1$ standard deviation—that is, between soil resistivity limits 615 ohm-cm and 2,030 ohm-cm. This is because 15.865 per cent of the measurements will be less than 615 ohm-cm and 15.865 per cent will be greater than 2,030 ohm-cm. Similarly, 95.45 per cent of the measurements (46.8 theoretical against 47 actual) will lie inside the range -2 to $+2$ standard deviations. Thus, for the distribution in question, it is improbable that more than three measurements in a sample of 1,000 will be either smaller than 187 ohm-cm or larger than 6,700 ohm-cm. Further use will be made later of such probability boundaries for normal distributions.

Uniformity and High Resistivity

In Fig. 3, 36 soil resistivities measured by the author over the right-of-way of a lateral to Capuava from the main oil pipelines of Estrada de Ferro Santos y Jundiai, São Paulo, Brazil, are plotted on a logarithmic scale against associated probabilities estimated from the sample size. These data are logarithmically normally distributed with parameters as displayed in Fig 3.

An interesting feature of this statistically uniform soil is the exceedingly high mean, or median, resistivity of 102,000 ohm-cm. The large standard-deviation quotient is consistent with the generally higher quotients in statistically uniform soils of higher mean resistivity. This soil would be considered, as will be seen from the exposition to follow, to be essentially noncorrosive.

Nonconforming Measurements

The lack of closer conformity of data in Fig. 3 to the logarithmic normal distribution, as evidenced by the several jumps or breaks in the trend, suggests that there may have been more than one class of soil involved in the measurements. It was earlier shown that it is feasible, although exceedingly tedious arithmetically, to determine a line of regression and to construct control limits as a basis for acceptance or rejection of the hypothesis that a given distribution is logarithmically normal. It is desirable, therefore, to have some simple method of separating nonconforming data into two or more conforming classes, if such subclasses indeed exist.

It will be shown, especially for arid and semiarid soils, that there is a relation between soil resistivity and corrosion. There are good reasons to expect that total corrosion, as measured by weight loss in a corroded specimen, is related linearly to soil conductivity. Accordingly a plot of soil conductivity with respect to a linear right-of-way would be proportional at any point to the corrosivity of the soil at that point.

The linear conductivity plot is especially useful in resolving into statistically uniform classes data which as a group do not indicate statistical uniformity. In such resolutions the component soils will be referred to as classes to avoid confusion with the US Bureau of Soils classification. The resolutions are by no means arbitrary, however. There is always a geographical or observational basis for resolution. Measurements of soil resistivity in the field, therefore, are accompanied by notes on elevation, drainage, soil texture, vegetation, rocks, sur-

face indications of alkali, and the like to aid in resolution, if the probability chart indicates a necessity for it.

To illustrate resolution of a set of nonconforming data, a very obvious example of 35 soil resistivity measurements made by the author for the soil. Accordingly, in Fig. 5 soil conductivities are plotted as ordinates with pipeline stationings as abscissas.

The conductivity k in mhos per centimeter is the reciprocal of the resistivity in ohm-cm. If the unit in k is taken more conveniently as micro-

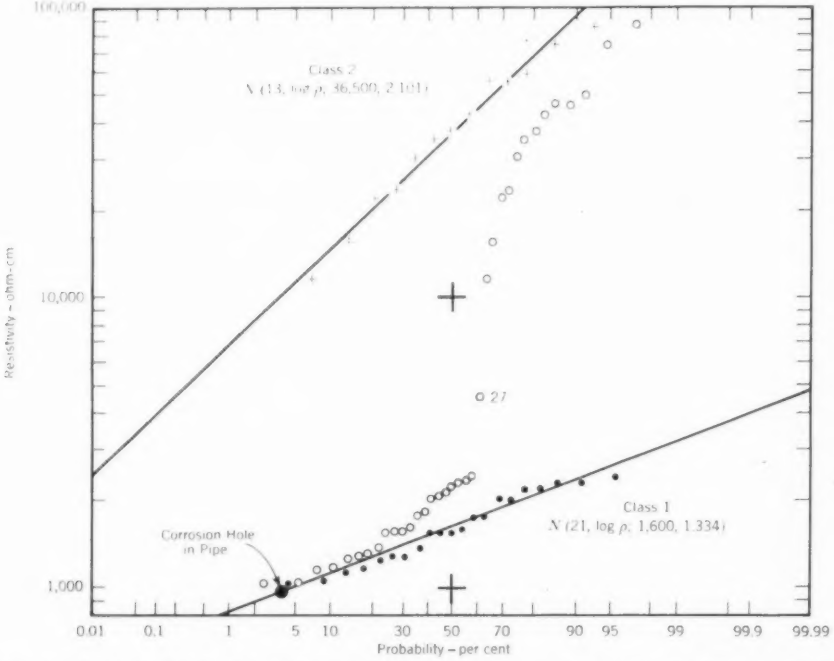

Fig. 4. Resolution of a Nonuniform Soil Into Two Classes of Statistically Uniform Soils

The 35 resistivity measurements (open circles) are not logarithmically normally distributed, but they may be resolved geographically and statistically into two uniform classes with the parameters shown. The occurrence of a rust hole at a resistivity well below the lowest resistivity in the random sample suggests that there is a relationship between soil resistivity and corrosion.

Hagginwood Sanitary District near Sacramento, Calif., is given in Fig. 4. The measurements are plotted as a probability distribution, in which the circled points clearly do not even approach the straight line that would be expected for a statistically uniform

mhos per centimeter, however, the curve of the relationship between the two quantities becomes an equilateral hyperbola.

$$\rho k = 10^6 \quad \ldots\ldots\ldots\ldots (11)$$

This convenient arrangement permits

the construction of a corrosion classification scheme pivoted about the number 1,000, because, when $\rho = 1{,}000$ ohm-cm, $k = 1{,}000$ μmho/cm.

Thus the use of the conductivity plot depends to some extent upon the range in data. Occasionally, plots of both k and ρ are of assistance in resolving the data. As a consequence of the symmetry, a small change in one variable in a certain range effects a large change in the other and, similarly, in a certain other range a small change in the second quantity effects a large change in the first. The argument is clear when the curve of Eq 11 is constructed.

The measurements in Fig. 5 form two distinct groups which are geographically separated at approximately the 8,000-ft mark. There are no measurements between 11,000 ft and 12,000 ft because the pipe there is suspended beneath a bridge across the Sacramento River.

By a process similar to that applied in Fig. 1, control limits within which data of a set fall with a high degree of probability are drawn in Fig. 5 at ± 3 standard-deviation quotients from the mean. The control limits are shown as two sets of dotted lines parallel to the solid lines, which represent the geometric means or medians of the two sets of data. The control lines show that the conductivity ranges of the two classes of soils are mutually exclusive; they do not overlap.

Test 27 is excluded from both soil classes. Such a datum can be said to have an assignable cause for nonconformity. The measurement was taken at an angle in the pipeline where the line across open country joined a county road and turned parallel to it. The measurement was taken on the edge of the gravel road, which was, no doubt, constructed of imported material not characteristic of the surrounding soil. Also, at this point the pipeline is supported aboveground on concrete bents. This measurement may be accordingly rejected. The two points adjacent to it are connected with a dotted line in Fig. 5, thus, in effect, excluding the spurious measurement from the set. The two sets of measurements thus geographically separated are replotted in Fig. 4 as dots and crosses. They define two statistically uniform soil classes with parameters as shown. The rejected measurement is not used.

Conductivity and Corrosion

In the exposition to follow it will first be proved beyond a reasonable doubt that there exists a relation between soil conductivity and corrosion. The form of the relationship will then be deduced from Ohm's law. Although beyond the scope of this paper, the development will be completed by relating corrosion to time on an experimental basis. Area for further investigation will be indicated.

Experimental Verification

In the foregoing examples, a nonconforming soil was resolved into two conforming classes by means of a plot of soil conductivity with respect to right-of-way. If total corrosion is proportional to soil conductivity, the chart displays likely areas for maximum corrosion, which, according to Fig. 5, would occur in the first 7,500 ft.

The first leak occurred in this 16–17-year-old pipeline in the middle of the stretch (approximately the 3,500-ft mark). The soil resistivity measured at the leak was such that it could be located on the curve of Fig. 4; it will be noted that the resistivity at the

large black dot (leak point) is less than all others measured. Once the position and resistivity are known the leak may also be plotted as in Fig. 5. The probability of finding a soil of such a low resistivity is 0.06 (6 per cent). This may be interpreted to mean that the probability of a leak's occurring is only 6 per cent. If 100 measurements of soil resitivity were made, only 6–7 measurements would have a resistivity less than 1,000 ohm-cm. It is not likely, therefore, that the one leak to date should have occurred at such a low resistivity by chance alone. Although the evidence for the alleged cause of the rust hole in this instance was striking, it was not entirely convincing.

To show better odds that pipeline leaks occur in soils of low resistivity more complete data are listed in Table 3. These data have been presented elsewhere in graphical form.[2] All ten leaks listed occurred at resistivities well below the mean of 1,820 ohm-cm. The leak at the highest resistivity (1,100 ohm-cm) corresponds in the symbolically characterized, statistically uniform soil to a probability of 0.31 (percentage probability of 31). That there is a relation between the occurrence of these leaks and soil resistivity is evident from the table. The evidence is more striking if the leaks are plotted on the straight line of the median and slope determined by the soil parameters.

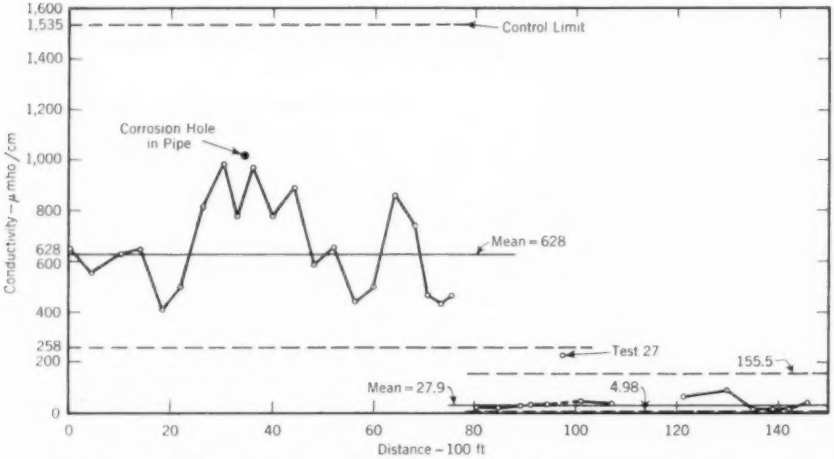

Fig. 5. Data Plot of a Right-of-Way Through a Nonconforming Soil Area

The geographic conductivity plot is used to resolve the data into two statistically uniform soil classes. Measurement 27 can be statistically rejected.

A numerical value of probability of the chance occurrence of the ten leaks is still more convincing. The cumulative probability that a leak will occur by chance at a resistivity equal to or less than 1,100 ohm-cm is 0.31. The probability that two leaks will occur at this resistivity or less is $(0.31)^2$ or

0.0961, and so forth. The probability that ten leaks would occur by chance at resistivities equal to 1,100 ohm-cm or less is very small:

$$P\ (\rho \lesssim 1{,}100) = (0.31)^{10} = 8.2 \times 10^{-6}.$$

The chance that ten leaks should occur purely by chance at resistivities less than 1,100 ohm-cm is, in other words, only 8 in 1,000,000. One is thus forced to conclude that corrosion in this statistically uniform soil is related in some manner to resistivity.

Similar proof of the existence of an undefined relationship results from estimating probabilities in numerous cases where it is consistently found that leaks occur at resistivities well below the mean. The problem of computing the probability in this case is the familiar one of estimating, for example, the odds (chances) of making a tossed coin land "heads" a certain n consecutive times. The chance of such an event on one toss is 0.5, on two tosses, $(0.5)^2 = 0.25$, and on n tosses $(0.5)^n$.

The leaks arranged in Table 4 are taken from several recent reports and private papers by the author. The chance that 29 leaks will occur at resistivities less than the mean is

$$P\ (\rho \lesssim \text{mean}) = (0.5)^{29} = 1.85 \times 10^{-9}.$$

The probability that the 29 leaks will fall by chance at resistivities at or below the means is less than 2×10^{-8}. If the soil resistivity had nothing to do with the leaks, the probability would be 0.5—that is, the leaks would be equally distributed above and below the mean resistivity. Thus there can be no doubt that the occurrence of leaks in the soils under consideration is related to resistivity. The form of the relationship, not indicated by the analysis, is described below.

Form of Relationship

If one writes Ohm's law with the voltage E as the independent variable and substitutes for the resistance R the equivalent expression

$$R = \rho\, f(g) = f(g)/k$$

then

$$I = k\, E/f(g) \quad \ldots\ldots\ldots (12)$$

In all expressions for resistance of electrolytic circuits the resistivity enters linearly. This follows from the definition of resistivity according to the formula

$$R = \rho\, L/A = \rho\, f(g)$$

TABLE 3

*Resistivities at Leak Locations With Associated Probabilities in a Statistically Uniform Soil**

Resistivity *ohm-cm*	Probability	Resistivity *ohm-cm*	Probability
1,100	0.31	720	0.19
1,040	0.30	440	0.085
1,030	0.29	430	0.080
900	0.25	340	0.048
860	0.24	290	0.037

* Data are from California Water Service Co. Bakersfield main; $N(34, \log \rho;\ 1{,}820,\ 2.113)$.

in which ρ, an intensive property of the conducting medium, is the proportionality constant connecting the resistance R of a rectangular electrolytic circuit directly with its length L and inversely with its cross-sectional area A. The form of this equation is typical. It follows that, for all electrolytic circuits, the resistance between an anode and a cathode depends upon ρ (or k) and a purely geometrical factor $f(g)$ which takes into account the configurations and disposition of the anode and cathode in the conducting medium. Dwight [7] contains many examples.

It is hardly necessary to justify the assumption of distinct anodic and cathodic areas on corroding pipe. The existence of such reacting surfaces is the basic concept of the electrochemical theory of corrosion. The incremental loss of metal at the anode will be linked through the proportionality constant C to current strength I and to the interval of time dT during which the current flows. Hence the total coulombic

TABLE 4

Division of Leaks in Accordance With Geometrical Mean Soil Resistivity

Example	No. of Leaks	
	Less Than Mean Resistivity	Greater Than Mean Resistivity
1*		
a	3	0
b	†	†
c	1	1‡
d	1	0
e§	10	0
f	2	0
2‖	4	0
3§	7	0
4¶	1	0
Totals	29	1

* Confidential Summary. July 28, 1958.
† Qualitative data; see Scott.[1]
‡ Leak proved to be caused by cathodic interference; rejected as having assignable cause other other than soil corrosion.
§ Ref. (*2*).
‖ Ref. (*1*).
¶ See Fig. 5.

equivalent, or weight loss w, will be the integral

$$w = C \int_0^T I \, dT = C \int_0^T k \, E \, dT / f(g)$$

To integrate the equation it is necessary to find expressions for k, E, and $f(g)$ in terms of Time T—a formidable task. For present purposes one may assume that both the soil conductivity k and the geometrical function $f(g)$ are constant. Taking the logarithm yields the expression

$$\log w = \log k + \log \left(\frac{C}{F(g)} \int_0^T E \, dT \right) \quad (13)$$

Several important deductions may be made from the equation in this form.

1. The logical measure of underground corrosion is the loss in weight w of the corroding specimen. Depth of pitting P, and hence leaks on a pipeline, is a derivative of the more fundamental measure w; the relationships between w and P was the subject of a recent (as yet unpublished) paper by the author.[6] The elementary development above follows closely the presentation in that paper.

2. If the factors in the second term on the right of Eq 13 are constant, then, because the logarithm of ρ (or k) is normally distributed, it follows that at any given time w will be logarithmically normally distributed. This was shown to be so in a reference cited previously.[2]

3. The relation between soil conductivity k and pitting (or the development of a hole in a pipe, which is a special case of pitting) will not necessarily be linearly related to k, in view of Eq 13, but will be dependent upon the connection between weight loss w and pitting P (and leaks) as derived in the reference cited.[6]

4. If a search is to be made for an analogue of E, efforts should be confined to statistically uniform soils in which the distribution of the analogue may be investigated without the complication inherent in tests in soils of two or more classes.[2] Thus, attempts to correlate redox potentials, pitting on a pipe, or other measurements with soil conductivity would probably be more successful if correlations were confined to statistically uniform soils.

Effective Cell Voltage

In the development of the author's physical theory of underground corrosion,[8] it was shown and supported by measurement that the expected rate of underground corrosion was inversely proportional to the square root of time of exposure. One may therefore write

$$E = \tfrac{1}{2} E_1 T^{-\frac{1}{2}} \quad \ldots\ldots\ldots\ldots (14)$$

If it is assumed that soil conductance and the geometrical factors remain constant, Eq 13 can be integrated, after the appropriate substitution, to obtain

$$w = \frac{C k E_1}{f(g)} (T^{\frac{1}{2}} + B) \quad \ldots\ldots\ldots (15)$$

The integration constant B represents the period of incubation before underground corrosion starts so that finally

$$w = (C k E_1)(T - T_0)^{\frac{1}{2}}/(f(g)) \ldots (16)$$

The equation portrays the dependence of corrosion as measured by loss in weight w upon soil conductivity k, initial galvanic voltage E_1 (at time T_1), the geometrical relation between anode and cathode $f(g)$ (which, in this instance, is assumed to be independent of time), and finally, upon the time T and the incubation period T_0.

Summary and Conclusion

Following are some results and consequences arising singly or jointly from the linear soil conductivity plot, the logarithmic normal distribution of soil conductivity, and the relation between underground corrosion and soil conductivity.

1. The cumulative probability chart provides an almost ideal way to display soil resistivity data.

2. The logical definition of a statistically uniform soil is shown to be one in which soil conductivities conform to a distribution that is logarithmically normal.

3. A simple, compact, and accurate way to describe a statistically uniform soil is provided.

4. The analyses prove beyond a reasonable doubt that underground corrosion, however measured (even qualitatively), is related in a uniform soil to soil conductivity; the linear form of the relationship between the corrosion as measured by loss in weight and soil conductivity may be deduced from Ohm's law.

5. A basis for classification of soils with respect to corrosive quality as gaged by soil conductivity (or resistivity) is virtually dictated; the pivot of such classification would be a resistivity of 1,000 ohm-cm (equivalent to a conductivity of 1,000 μmho/cm); the partitions between corrosive classes would occur as a consequence of the logarithmic normal distribution at multiples of two (or one-half) of the pivot. For example, resistivity (or conductivity) boundaries would be 250, 500, 1,000, 2,000, and 4,000 ohm-cm (or micromhos per centimeter), respectively.

6. The soil parameters of incomplete sets of resistivities measured for example, by probe-type instruments which do not indicate resistivities above 10,000 ohm-cm can be determined in statistically uniform soils by the analytical procedure, and if necessary, missing data can be estimated with a high degree of probability.

7. The analytical procedure provides a rational basis for the exercise of engineering judgment on problems of underground corrosion; for example, the prediction of probable current strengths obtainable from galvanic anodes, their life, and related items.

8. The notion of a statistically uniform soil and the linear conductivity plot serve together to resolve noncon-

forming sets of resistivity measurements into two or more statistically uniform soils.

9. The concept of a statistically uniform soil and the use of a linear conductivity plot serve to correlate conductivity with such variables as elevation, drainage, vegetation, alkali, rocks, soil texture, and the like.

10. A method is provided whereby one may choose a suitable soil area within which to conduct experiments to relate numerous soil characteristics or measurements, such as redox potentials and pit depths.

11. The conductivity-right-of-way plot provides an engineering basis for design of cathodic protection, which should be centered in areas of higher conductivity; there is a growing necessity to maintain minimum current waste, to minimize damage to coatings by the current, to avoid cathodic interference, and to provide maximum protection to a pipeline at minimum cost. Present practices seem to the author to be highly inefficient.

12. It is profitable to explore the nature of the exposure of any proposed underground structure before construction; the preliminary step is a soil conductivity survey, which may or may not be followed by chemical analyses, depending upon results of the preliminary survey and upon the composition of the proposed structure.

Acknowledgment

All soil resistivity measurements presented in this article were made personally by the author and have been used in this paper with the express permission of the companies for whom the data were originally taken. For this permission the author is grateful.

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Proposed Revision of AWWA Constitution and Bylaws

DURING 1958 it became apparent to the Executive Committee that amendments of the Constitution and Bylaws over the years since Jun. 25, 1929, when they were adopted, had introduced many inconsistencies, contradictions, and cross-reference problems. It was found, as a matter of fact, that if some of the language were followed literally, without reference to the remembered or assumed intent of the amenders, serious interference with the efficient operation of the Association could have resulted. Having become aware of this problem, the Executive Committee authorized the President to appoint an ad hoc committee to prepare a revision of the Constitution and Bylaws that would eliminate these difficulties.

In January 1959, the committee reported to the Executive Committee and to the Board of Directors that a complete redraft of both documents would be required to achieve the desired consistency. The committee was then given authority to proceed with the redraft that is presented herewith.

The redraft has been under review by the Association's standing committee on constitution and bylaws, by the Executive Committee, and by the members of the Board since June 1959. This review and considerable discussion of the original redraft have resulted in various changes. The draft presented herewith has received the approval of both the Executive Committee and the Board. It will be officially presented to the membership on Wednesday, May 18, at a general session of the 1960 Conference at Bal Harbour and, subsequently, a ballot form will be mailed to members asking their approval of the text. Unless serious objection is offered, the new constitution and bylaws will become effective on Jan. 1, 1961.

Significant Changes

Primarily the redraft is a mere restatement of the provisions of the present Constitution and Bylaws in which inconsistencies and contradictions between the two documents have been eliminated, and in which future inconsistencies and contradictions have been guarded against by the use of cross-references rather than repetition of provisions. Also, in the interest of efficient operation, a careful separation of basic, relatively permanent provisions and those which must be more flexible has been made—the former being included in the difficult-to-amend constitution and the latter in the more readily amended bylaws. But the occasion of the redraft has also been taken to effect a number of changes in both documents that recognize the growth of the Association since 1929 and that take into account the present organization of its activities.

In the constitution, which is the basic document and the one upon which the general membership will be asked to vote, the significant changes involve

primarily an increase in the number of signatures required for nominating officers and petitioning amendments, an increase in the membership of the Executive Committee from five to seven, and an increase in the required concurrence of the Executive Committee from a majority of the quorum to a majority of the whole committee. In the bylaws, which will be amended by action of the Board to integrate their provisions with those of the constitution, the differences are primarily those of nomenclature rather than of substance. Thus, the committees on Water Works Practice, Water Works Administration, and Publication have become more accurately committees on Standardization, Professional and Administrative Practice, and Technical Program. Beyond this, though, the present Junior Membership has been converted into a "Student Membership," in recognition of the fact that that has been its main function throughout, and the present requirements of petitioners for the formation of sections and divisions have been increased to recognize the growth of the Association.

There are other changes involved, too, such as the change in the title of "Secretary" to "Executive Secretary" and the redistribution of some of the duties of the Executive Secretary and the Treasurer in line with the practical operation of the Association. None of these effects any basic change in the structure of the Association, but they will, it is believed, facilitate the conduct of its affairs.

Presented here for your review and consideration is the proposed text of the new constitution and bylaws, together with outlines which refer each section of the new documents to the present Constitution and Bylaws. Your comments will be given full consideration by the Board at the Annual Conference in May of this year. And the final draft will be presented for your approval during the summer.

Outline of Draft Constitution

The left column shows the articles (roman numerals), sections (arabic numerals), and subjects in the draft; the right column indicates the numbers of the articles and sections in the present constitution dealing with the same subject. In a few instances, provisions of the new draft were based on provisions in the present Bylaws; these references are given in italics. Altogether new material is indicated by "new."

Draft Constitution	Compare Present Constitution
I. Name and Composition	
1. Name	I
2. Membership	
2.1. Description	II
2.2. "Active Member"	IV.3.1 (footnote)
3. Local Sections	new
II. Objects	II
III. Board of Directors	
1. Function	III.1
2. Membership	
2.1. Enumeration	III.2
2.2. Proxy	III.8
2.3. Plural office	new
3. Quorum	III.6
4. Meetings	III.7; IV.1.1
5. Executive Committee	III.5
6. Term of office	
6.1. Duration	IV.3.2; IV.4.1
6.2. Limits	III.3.1; IV.3.2
6.3. Late convention	III.3.2; IV.3.2
6.4. Extended term	new
6.5. Newly organized Section	IV.3.2
6.6. Consecutive terms	III.4
7. Manner of selection	
7.1. Section Directors	
7.1.1. Normal election	IV.3.1
7.1.2. Special cases	IV.3.3
7.2. WSWMA Directors	IV.4.1; IV.4.2
IV. Officers	
1. Titles and functions	*Bylaws: V.1; V.4.1; V.5.2*
2. Terms of office	
2.1. Duration	IV.2.1; *Bylaws V.5.1*
2.2. Special cases	IV.2.2; IV.2.3
2.3. Consecutive terms	III.4
3. Nomination and election	
3.1. Nominating Committee	IV.1.1
3.2. Petition	IV.1.2
3.3. Letter ballot	IV.1.2; IV.1.3
3.4. Voting procedure	IV.1.3; IV.1.4
3.5. Counting of ballots	IV.1.5
3.6. Results	IV.1.6
3.7. Late convention	new
4. Executive Secretary (appointment)	*Bylaws V.5.1*
V. Amendments	
1. Initiation	
1.1. Proposal	V.1.1; V.1.5
1.2. Board consideration	V.1.2; V.1.3
2. Discussion at convention	V.1.4; V.1.5; V.1.6
3. Letter ballot	V.1.7; V.1.8
4. Adoption	V.1.9; V.1.10

Outline of Draft Bylaws

Draft Bylaws	Compare Present Bylaws *
I. Membership Qualifications, Classifications, and Privileges	
1. Qualifications	I.2
2. Classifications and privileges	
a. Active	I.3
b. Junior	I.4
c. Corporate	I.5
d. Associate	I.6
e. Life	I.7
f. Honorary	I.8
3. Municipal Service Subscribers	I.9
II. Admission and Expulsion	
1. Application	II.2.1; II.2.2
2. Endorsement	
2.1. Active or Student	II.2.1

* Altogether new material is designated "new."

Draft Bylaws	Compare Present Bylaws *
2.2. Corporate	new
2.3. Associate	II.2.2
3. Admission	
3.1. Committee on Admissions	II.1.1
3.2. Board notification	II.1.2; II.1.3
3.3. Referral	II.1.3
3.4. Approval	II.1.4; II.1.5
3.5. Effective date	II.1.6
4. Election of Honorary Members	
4.1. Procedure	II.3.1; II.3.2
4.2. Limitation	II.3.3
5. Resignation	II.7
6. Suspension and expulsion	
6.1. Nonpayment	II.5
6.2. Other causes	II.8; II.2.2
III. Dues and Fees	
1. Payment of annual dues	
1.1. Membership dues	III.1
1.2. Municipal Service Subscribers	III.5
1.3. Changes in dues	III.6
2. Remission of dues	II.4
3. Subscriptions included in dues	new
4. Arrears	
4.1. Dues	II.5
4.2. Other charges	new
4.3. Reinstatement	II.6
IV. Duties of Officers	
1. President	V.1
2. Vice-President	V.1; V.2
3. Treasurer	
3.1. Duties	V.4.1; V.4.3
3.2. Bonding	V.4.2
4. Executive Secretary	
4.1. Staff	V.5.2
4.2. Duties	V.5.3–V.5.7; V.5.9; V.6.1; V.6.2
4.3. Bonding	V.5.8
V. Conventions and Board Meetings	
1. Conventions	
1.1. Time and place	VI.1.1
1.2. Registration fee	VI.1.3
2. Board meetings	
2.1. Convention	V.3.1
2.2. January	new
2.3. Late convention	V.3.2
2.4. Notification	V.3.1
3. Section meetings	VI.1.1
4. Rules	VI.1.2; V.3.3
VI. Executive Committee	
1. Appointment	IV.1.1
2. Officers	IV.1.2
3. Meetings	IV.1.4
4. Powers	new
VII. Standing Committees	
1. General Policy Committee	IX.1
2. Committee on Standardization (Water Works Practice)	new (IX.2)
3. Committee on Professional and Administrative Practice (Water Works Administration)	new (IX.3)
4. Technical Program Committee (Publication Committee)	new (IX.4)
5. Other committees	IX.5
VIII. Sections and Divisions	
1. Section formation	VII.1.1
2. Section boundaries	VII.1.1
3. Regional branches	VII.1.2
4. Diverse residence	VII.1.3; VII.2.1; VII.3
5. Section allotments	
5.1. Computation	VII.4.1; VII.4.2; VII.4.7
5.2. Application	VII.4.3
5.3. Special cases	VII.4.3; VII.4.8
5.4. Sharing of allotment credit	VII.3.4
6. Authorized use of Section allotments	VII.4.4
7. Section assessments	VII.4.9
8. Section accounts	
8.1. Procedure	VII.4.5
8.2. Audit	VII.4.6
9. Association Divisions	
9.1. Formation	VII.5
9.2. Expenses	VII.6
10. Section and Division government	VII.7
11. Dissolution	VII.8
IX. Amendments	
1. Board action	X.1
2. Executive Committee action	X.2

* Altogether new material is designated "new."

CONSTITUTION

ARTICLE I

Name and Composition

Sec. 1. *Name.* The name of this Association shall be "American Water Works Association" (abbreviated "AWWA").

Sec. 2. *Membership:*

2.1. The membership of the Association shall consist of persons and organizations interested in and in accord with the objects set forth in Art. II. Qualifications for and classification of membership shall be as prescribed in the Bylaws.

2.2. The term "Active Member" as used in this Constitution shall include all persons having the rights and privileges of Active Members under the Bylaws.*

Sec. 3. *Local Sections.* There shall be local Sections established by the Board of Directors as prescribed in the Bylaws.

(*Constitution*)

ARTICLE II

Objects

The objects of the Association shall be:

a. To advance the knowledge of the design, construction, operation, and management of water utilities

b. To consider and deal with the problems involved in the production and distribution of safe and adequate water supplies

c. To promote satisfactory relationships with the consuming public

d. To give proper consideration to and express opinions upon practices which will enable the industry to render the best possible service to the public

e. To do whatever things are necessary and proper for the accomplishment of the objects herein set forth, all of which shall be consistent with the public interest and with the interests of the public water supply field.

(*Constitution*)

ARTICLE III

Board of Directors

Sec. 1. *Function.* The affairs of the Association shall be managed by a Board of Directors. The Board may enact bylaws not inconsistent with the provisions of this Constitution.

Sec. 2. *Membership:*

2.1. The Board shall consist of:

a. The President of the Association

b. The Vice-President of the Association

c. The Treasurer of the Association

d. The latest living Past-President of the Association

e. One Director to be elected by each Section of the Association

* The Bylaws currently grant such rights and privileges to Honorary and Life Members, as well as to accredited representatives of Corporate Members or Municipal Service Subscribers.

f. Three Directors to be designated by the Water and Sewage Works Manufacturers Association

g. Such Standing Committee chairmen as the Bylaws may designate.

2.2. No Board member may be represented by any other person in any action required of him as a Board member.

2.3. No officer shall serve as a Director representing a Section or the Water and Sewage Works Manufacturers Association, nor shall any Director represent both the Manufacturers Association and an AWWA Section at one time.

Sec. 3. *Quorum.* A quorum of the Board shall consist of a majority of its members.

Sec. 4. *Meetings.* Regular meetings of the Board shall be held in January of each year and, also, at the time and place of the annual convention, on such days as may be fixed by the Board. Special meetings may be held at the direction of the President, or at the written request of five members of the Board, and on such notice as shall be prescribed in the Bylaws.

Sec. 5. *Executive Committee.* The Board shall appoint an Executive Committee of seven of its members, including the President, Vice-President, Treasurer, and latest living Past-President. Between meetings of the Board, the Executive Committee shall, to the extent provided in the Bylaws, have and exercise all of the authority of the Board in the management of the Association. Four members of the Executive Committee shall constitute a quorum thereof, but no action shall be taken without the concurrence of a majority of the whole Committee.

Sec. 6. *Term of office:*

6.1. The terms of Directors representing Sections or the Water and Sewage Works Manufacturers Association shall be for approximately three years.

6.2. In a year when the annual convention is scheduled to begin before August 15, the terms of newly selected Directors shall commence—and the terms of their predecessors shall end—at 12:01 AM of the last scheduled day of the convention.

6.3. In a year when the annual convention is not to be held, or will not begin before August 15, the terms of newly selected Directors shall commence—and the terms of their predecessors shall end—at 12:01 AM on July 1.

6.4. Sections 6.2 and 6.3 notwithstanding, a Director shall continue in office beyond the prescribed expiration date of his term if his successor has not been chosen before then. In that case, his tenure shall end and his successor's tenure shall begin when notice of selection is acknowledged by the Executive Secretary. But no Director's tenure shall be extended beyond the conclusion of the next regular meeting of the Board (Art. III, Sec. 4). The expiration date of a Director's term shall not be changed by reason of his taking office after the normal commencement date.

6.5. The Board shall fix the limits of the term of the first Director representing a newly established Section.

6.6. No Director shall serve a second term consecutively. This prohibition shall not apply to a Director chosen to fill out an unexpired portion of a predecessor's term if selected subsequent to the annual convention first preceding the end of the term.

Sec. 7. *Manner of selection:*

7.1. Directors representing Sections shall be selected as follows:

7.1.1. Each Section shall elect one Director from among its Active Members, in a manner consistent with its bylaws. If a Director ceases to be a member of the Section that elected him, he shall be replaced as prescribed in Sec. 7.1.2 of this Article.

7.1.2. When, for any reason, a Director fails to complete his term, a successor to serve for the remainder of the term shall be elected by the Section members as prescribed in the bylaws of the Section or appointed by the governing body of the Section.

7.2. The Water and Sewage Works Manufacturers Association shall designate three Directors. If a Director fails to complete his term, the Manufacturers Association shall designate a successor to serve for the remainder of the term.

(Constitution)

ARTICLE IV

Officers

Sec. 1. *Titles and functions.* The officers of the Association shall consist of the following:

1.1. The *President*, who shall have general supervision of the affairs of the Association, performing such additional duties as the Bylaws may prescribe.

1.2. The *Vice-President*, who shall assist the President in the performance of his duties and act in his stead when required.

1.3. The *Treasurer*, who shall have supervision of the funds of the Association, carrying out his responsibilities in regard to them as the Board of Directors may require.

1.4. The *Executive Secretary*, who shall be the chief administrator of the Association.

Sec. 2. *Terms of office:*

2.1. The terms of the President, Vice-President, and Treasurer shall be for approximately one year, with the limits to be fixed as provided for Directors in Art. III, Sec. 6.2 and 6.3. These officers shall, however, continue in office until their successors have been chosen. The Executive Secretary shall serve at the pleasure of the Board, but the Executive Committee shall have power to suspend him from office if such action is clearly in the interest of the Association.

2.2. If the President fails to complete his term, the Vice-President shall act in his stead for the remainder of the term. If the Vice-President cannot act, the latest living Past-President shall do so. If the Past-President cannot act, the Executive Committee shall appoint an Acting President. If the Treasurer fails to complete his term, the Executive Committee shall appoint an Acting Treasurer. Such appointees must meet the qualifications set forth in Sec. 3.1 of this Article.

2.3. Neither the President nor the Vice-President shall succeed himself in his respective office. This prohibition shall not apply to a person acting as President under the provisions of Sec. 2.2 of this Article.

Sec. 3. *Nomination and election of President, Vice-President, and Treasurer:*

3.1. At the regular meeting of the Board of Directors in January, a Nominating Committee consisting of the Directors representing the various Sections shall meet under the chairmanship of the President. The committee shall nominate one, and may nominate a second, candidate for each of the offices of President, Vice-President, and Treasurer. The candidates must be Active Members, must be past or present members of the Board of Directors, and must signify willingness to accept nomination. The Committee shall report its list of nominees to the Board before the close of the January meeting, and the list shall be mailed to the membership before February 1 of that year.

3.2. At any time prior to noon on March 1, additional candidates meeting the qualifications set forth in Sec. 3.1 of this Article may be nominated by a petition signed by at least 50 Active Members and filed with the Executive Secretary.

3.3. If only one candidate has been nominated for an office by noon on March 1, he shall be considered elected. When more than one candidate has been nominated for an office, the Executive Secretary shall prepare a letter ballot listing the nominees in alphabetical order, with their place of residence, and indicating those named by the Nominating Committee. The ballot shall be mailed to each Active Member prior to April 1.

3.4. Every Active Member shall be entitled to vote for one candidate for each of the offices appearing on the ballot. The voter shall seal his marked ballot in a special envelope provided, enclose the latter in a larger envelope bearing his signature, and mail it to the Executive Secretary.

3.5. The Executive Secretary, together with two or more Tellers appointed by the President, shall open and count all valid ballots at a time and place fixed by the President. The time shall be not less than three nor more than twelve days before the new term of office begins. No ballot received later than noon of the twelfth day shall be counted.

3.6. The Tellers shall certify their count to the President in writing, and he shall announce the results at the annual convention. The candidate with the highest number of votes among all the candidates for a particular office shall be declared elected. If there is a tie, the President shall order a ballot taken among the Active Members present at the convention to break it.

3.7. If the balloting takes place in a year in which the annual convention is not to be held or will not begin before August 15, the President shall, before July 1, announce the results of the Tellers' count to the Executive Committee, which shall declare the candidates with a plurality elected. In the event of a tie, the President shall call a meeting of the Board of Directors during July, at which time they shall vote to break the tie.

Sec. 4. *Appointment of Executive Secretary.* The Executive Secretary shall be appointed by the Executive Committee, subject to confirmation by the Board of Directors.

(*Constitution*)

ARTICLE V

Amendments

Sec. 1. *Initiation:*

1.1. Amendments to this Constitution may be proposed by the Board of Directors or by a written petition signed by either (a) ten or more Active Members of each of a majority of the Sections or (b) 250 or more Active Members, regardless of Section. The Executive Secretary shall submit such petitions to the next meeting of the Board scheduled to take place at least 30 days after he receives them.

1.2. The Board shall consider the proposals, and its opinion shall be transmitted to the proposers by the Executive Secretary not later than 21 days after the conclusion of the meeting. The proposers may then withdraw their proposals, accept any change suggested, or insist on the original form, sending their decision to the Executive Secretary not later than 30 days after the date of the Executive Secretary's notice of the Board's action.

Sec. 2. *Discussion at convention.* Proposals, whether initiated by the Board or by petition, shall be mailed by the Executive Secretary to the Active Members not less than 21 days prior to the next annual convention and shall be scheduled for discussion there. If, as a result of such discussion, the proposers then desire to withdraw or modify their proposals, they shall notify the Executive Secretary within 30 days after the close of the convention. He shall thereupon transmit their decision to the Executive Committee for approval. If the Committee approves the proposers' modifications, the proposals shall be submitted as modified to the Active Members in accordance with Sec. 3 of this Article. If the Committee disapproves modification or withdrawal, the original proposals shall be submitted to the Active Members in accordance with Sec. 3.

Sec. 3. *Letter ballot:*

3.1. Not more than 90 days after the close of the convention, the Executive Secretary shall mail to all Active Members a letter ballot on such proposals as have not been withdrawn. On the written request of ten or more Active Members, the letter ballot shall be accompanied by a statement giving arguments for and against a proposal. This statement shall be edited by a committee appointed by the Board of Directors, consisting of an equal number of members favoring and members opposing the proposal.

3.2. The letter ballot shall be returnable to the Executive Secretary not later than 120 days after the close of the convention. Three Tellers appointed by the Board of Directors shall forthwith count the ballots and report the results to the Executive Secretary, who shall, in turn, inform the Board.

Sec. 4. *Adoption:*

4.1. Affirmation by a two-thirds majority of all valid ballots shall be necessary for the amendment of any part of this Constitution.

4.2. The amendments passed shall take effect at the beginning of the next calendar year, except that changes affecting the tenure of office of an elective officer (Art. IV, Sec. 2.1) shall not take effect until the next annual convention.

BYLAWS

ARTICLE I

Membership Qualifications, Classifications, and Privileges

Sec. 1. *Qualifications:*

1.1. All members shall have a recognizable interest in the furtherance of the objects of the Association as set forth in Art. II of the Constitution.

1.2. No member shall carry on a business or profession other than in a fully ethical manner and in conformity with generally accepted principles of conduct.

1.3. Every member not specifically exempted shall pay the dues and fees established for his class of membership in accordance with Art. III of these Bylaws.

Sec. 2. *Classifications and privileges.* The membership of the Association shall consist of:

a. Active Members—individuals such as water utility personnel, municipal officials, public health workers, engineers, scientists, educators, consultants, and others who meet the qualifications in Sec. 1 above.

b. Student Members—regularly enrolled college or university students. Student Members shall be entitled to all the rights and privileges of Active Members except holding office and voting.

c. Corporate Members—organizations engaged in supplying water for public or other use; government agencies; and firms engaged solely in consulting practice. Each Corporate Member shall be entitled to name a representative, who shall have all the rights and privileges of an Active Member. A representative may be changed on written notice to the Executive Secretary.

d. Associate Members—firms or corporations engaged in the manufacturing or furnishing of products or services in connection with water supply. Each Associate Member shall be entitled to name a representative, who shall have all the rights and privileges of an Active Member except holding office and voting.

e. Life Members—individuals who have continuously for 30 years been Active Members or accredited representatives of Corporate Members, or a combination thereof. The Board of Directors may, at its discretion, confer Life Membership upon other individuals whose affiliation with the Association, in one form or another, has been continuous for 30 years. A Life Member shall have all the rights and privileges of an Active Member and shall be exempt from paying dues, but the granting of Life Membership to the representative of a Corporate Member shall not relieve the latter from the payment of dues.

f. Honorary Members—individuals whose knowledge and accomplishments in the field of water supply entitle them to special recognition. An Honorary Member shall have all the rights and privileges of an Active Member and shall be exempt from paying dues.

Sec. 3. *Municipal Service Subscribers:*

3.1. Municipal water departments, boards, or commissions desiring to receive all the publications and bulletins sent to Active Members may purchase a Municipal Service Subscription.

3.2. A Municipal Service Subscriber shall be entitled to all the rights and privileges of a Corporate Member. Whenever the term "Corporate Member" appears in these Bylaws, it shall be understood to include Municipal Service Subscribers, unless otherwise specified.

(Bylaws)

ARTICLE II

Admission and Expulsion of Members

Sec. 1. *Application.* Application for membership shall be made to the Executive Secretary on a form provided by the Association, shall include an adequate statement of the applicant's qualifications for membership, and shall describe precisely the nature of the professional or business activity in which the applicant is engaged. In addition, an applicant for Associate Membership shall be required to furnish specific information concerning the ownership, corporate structure, and financial standing of the applicant, together with the names of at least five customers from whose experience the applicant's reputation in the water supply field can be ascertained.

Sec. 2. *Endorsement:*

2.1 Applications for Active or Student Membership shall, whenever possible, be filed with the endorsement of a member of the Association. Unendorsed applications shall be referred by the Executive Secretary, for endorsement, to a member residing in the area where the applicant is located. If there are no members in that area, the Executive Secretary shall require the applicant to furnish such evidence of his professional standing and activity as will enable the Executive Secretary to endorse the application.

2.2. Applications for Corporate Membership shall be endorsed by the Executive Secretary after he has satisfield himself that the applicant meets the requisite qualifications.

2.3. Applications for Associate Membership, together with the supplementary information prescribed in Sec. 1 of this Article, shall be referred to the Executive Committee of the Board of Directors for endorsement or rejection. The Executive Committee shall, with the Board's concurrence, establish such criteria as it deems necessary for determining whether applicants for Associate Membership meet the requisite qualifications.

Sec. 3. *Admission:*

3.1. There shall be a Committee on Admissions, which shall consist of three members of the Board of Directors appointed by the President with the consent of the Board.

3.2. The Executive Secretary shall notify the Board of Directors of applications endorsed as prescribed in Sec. 2 above. The Board member representing the Section to which an applicant will be assigned if accepted shall in-

form himself as fully as reasonably possible concerning the business practices and general reputation of the applicant.

3.3. If any Board member desires an application to be reserved for action by the Board, he shall so advise the Executive Secretary; otherwise the application shall be referred to the Committee on Admissions.

3.4. Approval of applications referred to the Board for action at any meeting shall require a majority vote of those present. Approval of applications referred to the Committee on Admissions shall require a unanimous vote of that Committee.

3.5. Election to membership shall not become effective until the annual dues of the applicant have been paid.

Sec. 4. *Election of Honorary Members:*

4.1. A Committee on Honorary Membership, consisting of the President and the first and second most recent living Past-Presidents, the latter serving as chairman, shall, on its own initiative or at the request of 25 Active Members, consider the qualifications of individuals for Honorary Membership. The Committee shall report its nominees to the Board of Directors at any regular meeting thereof. The Board may vote on nominees for Honorary Membership only at its January meeting. Election shall be by secret ballot and shall not carry if more than one negative vote is cast.

4.2. No election to Honorary Membership shall be made if it would cause the total number of such members to exceed 1/150 of the total number of Active Members. The maximum number of Honorary Members who may be elected in any single year shall be four, plus one for each 1,000 Active Members in excess of 10,000.

Sec. 5. *Resignation.* Any member in good standing may resign from membership by giving written notice to the Executive Secretary. Such action shall not entitle a member to a refund of dues or relieve him of the obligation to pay any charges he may have incurred during the period of membership.

Sec. 6. *Suspension and expulsion:*

6.1. A member who fails to pay the applicable dues and fees prescribed in Art. III may be suspended or removed from the rolls as provided in Sec 4 thereof.

6.2. Any member ceasing to meet the qualifications set forth in Sec. 1.1 and 1.2 of Art. I, or the criteria established by the Executive Committee in accordance with Sec. 2.3 of Art. II, or for other good cause, may be expelled from the Association by a three-fourths vote of the Board of Directors, provided such member has been given a written statement of charges preferred and has been accorded the opportunity of a hearing before the Board

(*Bylaws*)

ARTICLE III

Dues and Fees

Sec. 1. *Payment of annual dues:*

1.1. Each Active, Corporate, Associate, and Student Member shall pay annual dues in the amount currently in effect for his respective class of membership. Payment shall be due on the

first day of each annual period, and the Executive Secretary shall, prior to that day, notify each member of the amount due for the ensuing year.

1.2. Municipal Service Subscribers shall pay an annual fee equal to the annual dues of Corporate Members and shall receive the publications and services of the Association on the same basis as Corporate Members.

1.3. Changes in the amount of annual dues required for the various membership classes may be made by the Board of Directors in the manner prescribed in Art. IX for amendment of these Bylaws, provided that such action is completed not less than 90 days prior to the end of the calendar year preceding the effective date of such changes.

Sec. 2. *Remission of dues.* The Board of Directors may, for good cause, temporarily or permanently excuse from the payment of annual dues any member who, because of ill health, advanced age, or other disability, cannot pay such dues, and the Board may remit the whole or part of dues in arrears, or accept in lieu thereof desirable additions to the library or collections.

Sec. 3. *Subscriptions included in dues.* Each member's annual dues shall include the cost of a subscription to *Journal American Water Works Association*, *Willing Water*, and such other periodical publications of the Association as may be approved by the Board of Directors.

Sec. 4. *Arrears:*

4.1. A member whose dues are in arrears for three months shall be suspended, all rights and privileges of membership being withheld from him until such arrears are paid. Members in arrears for one year shall be automatically removed from the rolls by the Executive Secretary.

4.2. Members who fail to pay charges for materials, services, or advertising ordered on their behalf from the Association may, on 30 days' notice, be suspended by the Executive Secretary until the account is paid.

4.3. No member who has been removed from the rolls shall be reinstated until he has paid all arrears and other charges outstanding against him.

(*Bylaws*)

ARTICLE IV

Duties of Officers

Sec. 1. *President.* The President shall preside at all conventions of the Association and all meetings of the Board of Directors. The President shall be, ex officio, a member of such committees as he desires. He shall perform such other duties as may be specified elsewhere in these Bylaws or assigned by the Board of Directors.

Sec. 2. *Vice-President.* The Vice-President shall preside at conventions and Board of Directors meetings in the absence of the President. If the Vice-President is unable to preside, the President shall designate a presiding officer to act in his stead. The Vice-President shall be, ex officio, a member of such committees as he desires. He shall perform such other duties as may be specified elsewhere in these Bylaws or assigned by the Board of Directors.

Sec. 3. *Treasurer:*

3.1. The Treasurer shall have supervision of the funds of the Association.

He shall, with the advice and consent of a Finance Committee appointed by the Board of Directors, temporarily invest those funds to the extent warranted by the Association's cash position. He shall act as consultant to the Executive Secretary in all fiscal matters of the Association. He shall make such reports to the Board of Directors as may be appropriate in the discharge of these responsibilities. He shall perform such other duties as may be specified elsewhere in these Bylaws or assigned by the Board.

3.2. The Treasurer shall be bonded, at the expense of the Association, in an amount determined by the Board of Directors.

Sec. 4. *Executive Secretary:*

4.1. The Executive Secretary shall direct all staff activities. Appointments to the staff and dismissals therefrom shall be made by him with the advice of the President.

4.2. The Executive Secretary shall:

a. Prepare the agenda for, attend all meetings of, and record the proceedings of the Board of Directors and the Executive Committee.

b. Taking counsel with the chairman of the Technical Program Committee, prepare and publish the program of, and be present at, the conventions of the Association.

c. Be responsible for the content and distribution of the periodical and occasional publications of the Association.

d. Act as secretary of the Committee on Standardization, the Committee on Professional and Administrative Practice, and the Technical Program Committee.

e. Present for approval by the Board of Directors an annual budget prepared with the advice of the Treasurer and the Finance Committee.

f. See that all moneys due the Association are collected and promptly deposited to its credit, and that the Association incurs no indebtedness greater than its liquid assets; pay all proper charges against the Association; and submit to the Treasurer a monthly financial report, in such detail as he may request, with a summary thereof to each member of the Board of Directors.

g. Have charge of the books and records of the Association and make them available for audit, annually or as otherwise specified by the Board of Directors, by certified public accountants appointed by the Board.

h. Make such reports to the Board of Directors as are specified in these Bylaws, and such additional reports as he deems necessary or the Board may call for.

i. Perform such other duties as may be specified elsewhere in these Bylaws or assigned by the Board of Directors.

4.3. *Bonding.* The Executive Secretary shall be bonded, at the expense of the Association, in an amount determined by the Board of Directors.

(*Bylaws*)

ARTICLE V

Conventions and Board Meetings

Sec. 1. *Conventions:*

1.1. The annual convention of the Association shall be held at a time and place selected by the Board of Directors. Additional conventions may be held at such times and places as the Board directs.

1.2. Members and guests attending any convention shall each pay a registration fee, the amount to be determined by the Executive Secretary, with the advice of the Treasurer.

Sec. 2. *Board meetings:*

2.1. The Board of Directors shall hold two meetings at the time of the annual convention: one on the first day or the day preceding; the other on the last day or the day following.

2.2. The meeting of the Board of Directors in January shall convene no later than January 29.

2.3. In a year when the annual convention will not begin before August 15, the Board shall meet during July at the call of the President. It shall transact such business as is appropriate under the circumstances, including the appointment of committees whose term of duty would normally date from the annual convention.

2.4. The Executive Secretary shall notify all Board members at least ten days in advance of a meeting.

Sec. 3. *Section meetings.* Meetings of the Sections shall be held as prescribed by the bylaws of the Sections.

Sec. 4. *Rules.* All conventions and meetings shall be conducted according to the latest edition of "Robert's Rules of Order Revised." Except as otherwise provided in these Bylaws, all questions before the Board of Directors shall be decided by a majority vote. No Board member shall have more than one vote.

(*Bylaws*)

ARTICLE VI

Executive Committee

Sec. 1. *Appointment.* The Executive Committee (Constitution, Art. III, Sec. 5) shall be appointed at the meeting of the Board of Directors held (as prescribed in Sec. 2 of Art. V) at the close of the annual convention or in July.

Sec. 2. *Officers.* The President shall act as chairman and the Executive Secretary as secretary of the Committee. In the President's absence, the Committee shall choose a temporary chairman from its members.

Sec. 3. *Meetings.* The Committee shall meet at the call of the President or any four of its members.

Sec. 4. *Powers.* Between meetings of the Board of Directors, the Executive Committee shall have and exercise all of the authority of the Board in the

management of the Association, but the Committee shall not act for the Board under the provisions of Sec. 6.2 of Art. II, nor shall it take any action that will result in a change in the number of directors, nor shall the Committee's power to amend these Bylaws (Art. IX, Sec. 2) apply to this Article.

(*Bylaws*)

ARTICLE VII

Standing Committees

Sec. 1. *General Policy Committee:*

1.1. The General Policy Committee shall consist of the President; the four most recent living Past-Presidents; and two representatives of the Water and Sewage Works Manufacturers Association designated by it and acceptable to the AWWA Board of Directors. The chairman of the General Policy Committee shall be the latest living Past-President of AWWA.

1.2. The General Policy Committee shall consider such matters having to do with the general or long-term policy of the Association as are referred to it by the Board of Directors, the Executive Committee, or the President. The General Policy Committee shall submit any recommendations or policy statements formulated by it to the Board for consideration and further action.

Sec. 2. *Committee on Standardization:*

2.1. A Committee on Standardization, consisting of at least five members, shall be appointed by the incoming Board of Directors at the annual convention. The chairman of the Committee shall be, ex officio, a member of the Board.

2.2. Any statement or document which undertakes, in the name of the Association or of any of its Sections or Divisions, to establish a standard for a technical procedure or a material shall be submitted to the Committee on Standardization. The operations of the Committee shall be governed by the Standardization Procedure adopted by the Board of Directors.

Sec. 3. *Committee on Professional and Administrative Practice:*

3.1. A Committee on Professional and Administrative Practice, consisting of at least five members, shall be appointed by the incoming Board of Directors at the annual convention. The chairman of the Committee shall be, ex officio, a member of the Board.

3.2. The Committee shall consider matters of professional and administrative practice referred to it by the Board of Directors, the Executive Committee, or the President. In addition, the Committee on Professional and Administrative Practice shall, on its own initiative, take up such subjects within its province as it deems worthy of attention. The Committee shall submit any recommendations or policy statements formulated by it to the Board for consideration and further action.

Sec. 4. *Technical Program Committee:*

4.1. A Technical Program Committee, consisting of at least five members, including the chairmen of the Divisions, shall be appointed by the incoming Board of Directors at the annual convention. The chairman of the Com-

mittee shall be, ex officio, a member of the Board.

4.2. The Technical Program Committee shall advise and assist the Executive Secretary in preparing the technical program for the annual convention and in carrying out his responsibilities with regard to Association publications.

Sec. 5. *Other committees.* In addition to the standing committees established in this Article and elsewhere in these Bylaws, the Board of Directors may appoint such other standing or special committees as it deems necessary to further the objects of the Association.

(Bylaws)

ARTICLE VIII

Sections and Divisions

Sec. 1. *Section formation.* The Board of Directors may establish a Section on receipt of a written request signed by at least 40 Active or Corporate Members residing in the territory to be embraced by the Section.

Sec. 2. *Section boundaries.* Section boundaries shall be fixed by the Board of Directors and may be altered by it to meet the needs of members in the area affected. All Association members residing within the boundaries of a Section shall be members of that Section, except as provided in Sec. 4 of this Article.

Sec. 3. *Regional branches.* In order to advance the interests of the Association and the water supply industry, the Board of Directors may allow a Section to organize a regional branch in continental North America outside the limits of the United States, provided the branch membership will number at least 40.

Sec. 4. *Diverse residence:*

4.1. A member residing within the territory of one Section but having his principal place of business within that of another Section may, with the permission of the Board of Directors, elect to belong to the latter, with full rights therein.

4.2. A member whose residence is not within the territory of any Section may, upon written request to the Board of Directors, be included in the Section of his choice, with full rights, until such time as the territory of his residence is embraced by another Section.

4.3. A member whose residence and place of business both lie within one Section may apply to the Executive Secretary for permission to participate in the activities of a Section more conveniently located. The Executive Secretary shall transmit the request to the governing body of the latter Section for consideration. If the request is approved, the member shall be eligible to vote in and enjoy all the privileges of both Sections, except that he may not hold office in both simultaneously. Should a change in circumstances remove the reason for dual membership, it may be terminated by the member or his adopted Section.

Sec. 5. *Section allotments:*

5.1. Each Section shall be entitled to an annual allotment from Association funds, based on Active, Student,

and Corporate Membership dues and Municipal Service Subscription fees received by the Association through September 30 of the prior calendar year from members of the Section. The amount of the entitlement shall be 20 per cent of the dues and fees so received, but the minimum amount shall be $200. If, however, a Section has not used up all the funds received from previous allotments, and the unspent balance as of November 30 of the prior year is in excess of the current entitlement, then the entitlement shall be reduced by the excess.

5.2. At the regular Board of Directors meeting in January, the Executive Secretary shall submit a report listing the entitlement of each Section computed as above. After the Board has approved the report and the Association budget for the ensuing year, the Executive Secretary shall notify each Section secretary of the amount of his Section's allotment for the year, and shall provide a form for use in applying for the funds. Upon return of the application, properly signed by the Section secretary and endorsed by the Section chairman, the allotment shall be forwarded to the secretary.

5.3. Section officers are not required to apply for the full amount of the allotment to which the Section is entitled if a smaller amount will meet the Section's needs. Conversely, the Board of Directors may increase a Section's allotment for the coming year beyond its entitlement in order to defray the expense of special Section activities which the Board considers of material benefit to the Section and the Association.

5.4. In computing the annual allotment, the dues paid by a member belonging to two Sections simultaneously (under Sec. 4.3 above) shall be credited to the Section of residence unless the governing bodies of the two Sections agree to divide the credit.

Sec. 6. *Authorized use of Section allotments.* Association funds allotted to Sections shall be used only to carry on activities consistent with the Constitution and Bylaws of the Association and the bylaws of the Section. In questions of consistency, the Board of Directors shall be the final judge, and it may, from time to time, issue statements of policy on this subject. In any event, no portion of such funds shall be used to pay: dues or fees in any other association; expenses of any Section officer or member for travel outside the Section territory (except the expenses of a Section director, chairman, or secretary in attending meetings of an authorized regional branch of the Section); fees or expenses of any legislative agent or representative; charges accruing from social functions at Section meetings (except fees of professional speakers up to $50). The costs of social functions—including meals, entertainment, and other items—shall be paid by the Section out of its income from registration fees or sales of tickets for such events.

Sec. 7. *Section assessments:*

7.1. A Section may apply for permission to levy an assessment upon its members, not exceeding 50 per cent of Active Membership dues, in order to increase its funds available for Section uses consistent with Association objects and policies. An application setting forth the purposes of the assessment and approved by the governing body of the Section shall be filed with the

Executive Secretary for transmission to the Executive Committee. If the application is approved by the Committee, a letter-ballot vote of the Section membership shall be taken. If the vote is in favor, the application shall be submitted to the Board of Directors for approval.

7.2. When the above requirements have been fulfilled, the Executive Secretary shall, until directed to cease doing so, include the assessment in the dues bills sent to members of the Section. When payment is received, the assessment portion shall be remitted monthly to the Section secretary and entered in his accounts.

7.3. A Section may discontinue an assessment by taking appropriate action at a regular meeting or by letter-ballot vote of its membership. The Section secretary shall notify the Executive Secretary of such discontinuance.

Sec. 8. *Section accounts:*

8.1. Each Section secretary shall close his accounts as of November 30 of each year, and, not later than December 15 of that year, shall submit to the Executive Secretary a certified copy of his accounts, endorsed by the Section chairman. The accounts shall be itemized and shall show opening and closing balances (including cash, bank deposits, and investments) and receipts and disbursements during the report year separately for: (a) AWWA allotment funds; (b) meeting registration and ticket sale funds; and (c) all other funds to which the Section has title, from whatever sources derived. Parts (b) and (c) are intended for record purposes and for the information of the Board of Directors; they shall not be considered in determining the Section's allotment of Association funds unless the Section has requested a special allotment under Sec. 5.3 of this Article.

8.2. The Executive Secretary shall refer the Section accounts to an auditor selected by the Board of Directors. If the auditor reports that the expenditures have not been assigned in accordance with Sec. 8.1 above, or that the accounts are otherwise not in order, the Board of Directors shall take such action as it deems proper.

Sec. 9. *Association Divisions:*

9.1. At the request of 100 members, the Board of Directors may establish a Division concerned with a particular area of interest in the water supply field. Any member may participate in the activities of as many Divisions as he desires.

9.2. Statements of Division operating expenses shall be approved by the chairman and secretary of the Division before being forwarded to the Executive Secretary for payment. The annual operating expenses of a Division shall not exceed $100 unless the Board of Directors has previously approved a greater expenditure.

Sec. 10. *Section and Division government.* Sections and Divisions shall consist only of Association members in good standing. They shall elect their own officers and committees, and may adopt bylaws or amendments thereto which are not inconsistent with the Constitution and Bylaws of the Association and have the approval of the Board of Directors.

Sec. 11. *Dissolution.* Any Section or Division may be dissolved by the Board of Directors for reasons which it believes to be sufficient.

(*Bylaws*)

ARTICLE IX

Amendments

Sec. 1. *Board action.* The Board of Directors may amend these Bylaws by a two-thirds majority of those voting at any meeting of the Board, provided that a copy of the proposed amendment was mailed by the Executive Secretary to each Board member at least 30 days before the meeting.

Sec. 2. *Executive Committee action.* Subject to the limitations set forth in Sec. 4 of Art. VI, the Executive Committee may amend these Bylaws at any of its meetings by an affirmative vote of five members, provided that a copy of the proposed amendment was mailed by the Executive Secretary to all members of the Board of Directors at least 30 days prior to the Executive Committee meeting and that all comments received from Board members are considered fully before action is taken.

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(*Bylaws*)

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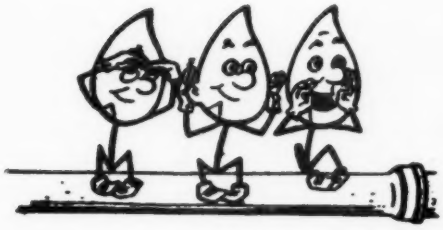

Percolation and Runoff

'Danger in Your Drinking Water,' *Good Housekeeping*'s frightening fare of January (see February P&R, p. 42), is now being offered in condensed form by the March *Reader's Digest*. Unlike the corporeal stuff, this food for thought has actually improved by being condensed, no doubt because the condensation was accomplished principally by deinsinuation rather than dehydration.

With its panic-striking implications removed, the article sounds a proper note of alarm concerning the rapidly growing problem with which the public water supply field is and will be faced in providing safe drinking water from poorer and poorer sources of supply, and it points to the need for public appreciation of this problem and support in its solution. In the addition of millions of *Digest* readers to at least a million good housekeepers already alert to the "Danger," water utilities will have a still bigger audience primed to understand their local problems and requirements and a convenient peg upon which to hang stories acceptable to their local newspapers.

Meanwhile, bearing the same tale to still more people have been many representatives of the USPHS. Thus, at the annual meeting of the National Audubon Society in November, Dr. David E. Price, assistant surgeon general, expressed fear that man might become an extinct species, succumbing to the chemical, radiological, and other pollutants he has produced. And at a meeting of the American Assn. for the Advancement of Science in December, H. W. Poston, director of water supply and pollution control at Chicago, pointed out that we do not know the effect on the human system of the constant accumulation of small increments of the 10,000 totally new chemicals which are put to use every year and which cannot be completely removed from waste waters. Meanwhile, in an article published in the Nov. 28 issue of the *Journal of the American Medical Association*, Dr. Leroy E. Burney, surgeon general, turned his attention to air pollutants in an article on "Smoking and Lung Cancer," in which he pointed out: "Unless the use of tobacco can be made safe, the individual's risk of lung cancer can be reduced best by the elimination of smoking."

As the elimination of drinking seems even more remote than the elimination of smoking, it appears that water utilities will have to continue to find ways of making water safe. Meanwhile, they will, no doubt, make the best of present "Danger" by acting to expose

(Continued on page 48 P&R)

(Continued from page 47 P&R)

themselves—however good or bad their local situations—to the glare of current public interest.

Current public interest, by the way, must have been at least slightly aglow in mid-January when President Eisenhower named John Daly, radio-TV news correspondent and analyst, to the USPHS Water Pollution Control Advisory Board. Either that or Ike's TV program transposed "What's My Line" and "Danger Is My Business!"

DiS-appointed and dammed within less than a month was Wendell LaDue, chief engineer and superintendent of the Akron, Ohio, water supply bureau. The appointment came on Nov. 17, when Governor DiSalle named him to the new Ohio Water Commission for a term lasting until April 1962. Then, on Dec. 15, the mayor and council of Akron passed a resolution designating the city's new Bridge Creek reservoir project, on completion, as the Wendell R. LaDue Reservoir. In congratulating AWWA Past-President LaDue on these two new honors, we know that they are no less earned or deserved than have been a hundred others which he has received from his city and state, from the Association and its sections, and from many of the other organizations to which he belongs. Perhaps he would have preferred billing here as "commissioned and impounded," but that sounded much more confined.

'Decisions, Decisions' was the caption that United Press International put on this photo of a confused canine in a state of arrested expression. The frustration was brought on by the Hartford, Conn., water utility, which installed a replacement for the hydrant at the left before removing it.

(Continued on page 50 P&R)

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ACCELAPAK® treating plant, complete in a single package for the treatment of surface or well waters in capacities from 15 to 350 g.p.m. Ideal for small communities, industrial plants or institutions.

Bulletin 1870-A.

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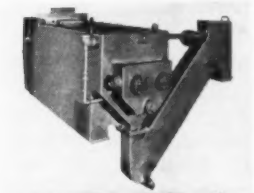

VISCOMATIC® slaker . . . Either high calcium or poor grades of lime are slaked in the form of a paste which is then diluted and fed as lime slurry. High paste temperature results in complete slaking without the need for hot water. Arranged for continuous grit removal.

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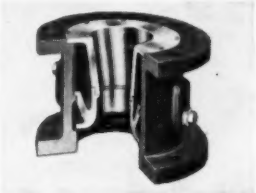

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Bulletin 1021.

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GENERAL PRODUCTS DIVISION
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ERIE, PA.

(Continued from page 48 P&R)

Remember Bal Harbour! The dates are May 15–20. The hotel reservation forms are returnable now. The preliminary technical and social programs appear on pp. 60–64. The best is up to you.

Mister X, at last, or, more properly, Senor X, for it is Elcio Xavier, public relations chief for the Compania Ferro Brasileiro, S.A., of Rio de Janeiro, who has become the first member ever to occupy the "X" bracket in AWWA records. We want to give a very special welcome to Senor X and thank him for making it possible now, after 79 years, for AWWA to claim that it has members from "A" to "Z" excepting not even "X."

A dog's life these days is being invaded by all kinds of researchers, primarily to find out why man's best friend so often puts the bite on him, but also to determine the reason for some of his other caninities. A recent study by a group of doctors from the University of Vermont, the University of Wisconsin, and the Allegheny County (Pa.) Health Dept., for instance, indicated that only one-third of all dog bites result from "malicious intent without human provocation." The other two-thirds are divided equally among dogs who are being played with and those who are being goaded. High-risk groups among dog-bite victims were found to include pre-school children, school children, and persons—including meter readers—who come to the dog owner's house in line of work.

Out of this study has come a number of conclusions: young dogs are worse biters than old dogs; females

(Continued on page 52 P&R)

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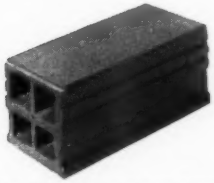

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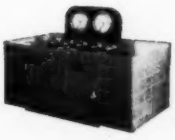

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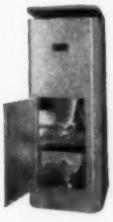

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(Continued from page 50 P&R)

bite oftener than males; boxers, collies, Eskimo dogs, German shepherds, great Danes, Saint Bernards, Doberman pinschers, pointers, setters, retreivers, and spaniels are more likely to bite than hounds; and dogs bite least in winter and most often in July and August. Out of another study have come seven points to caninization:

1. Never force yourself on a strange dog.

2. Never lean over a strange dog (you seem threatening); get down to his level.

3. Don't back a dog into a corner.

4. Talk in a low voice, using his name or calling him "good dog."

5. If the dog seems friendly, extend your hand slowly, with fist clenched; never extend your fingers.

6. Do not make sudden motions with your hand or body.

7. Bribe a dog with dogfood or dog candy.

But studies such as these are mere statistical compilations compared with an investigation undertaken by the Army's medical research laboratory at Fort Knox, Ky. There, three doctors have been able, by removing the prechiasmal area of a dog's brain, to make it ignore water. Even when dehydrated or injected with concentrated salt solution, dogs whose prechiasmal areas are missing show no interest in water. Undoubtedly the Army has some militant motive in this research, but strictly pacifically, too, deprechiasmalism in dogs ought, certainly, to serve a useful purpose in the protection

(Continued on page 53 P&R)

choice

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...can make a difference...

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(Continued from page 52 P&R)

of hydrants. Meanwhile, we can hope that postchiasmalectomy may prove to make dogs ignore not water, but water meter readers. Operation Dogbite, the Army can call it, and they will certainly find that it produces a significant reduction in the percentage of 4F's among water utility employees.

Meanwhile, as a general rule, one of our most hep kennelians suggests: "Dig the dog and dodge the dentures!"

Richard A. McQuade has rejoined Simplex Valve & Meter Co. as assistant to the general manager. Having served with Simplex from 1937 to 1955, he resigned to become sales manager of Penn Instruments Div., Burgess-Manning Co., a position he held until his present assignment.

(Continued on page 54 P&R)

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How many companies do you deal with when ordering pipe for your waterline? How divided is the responsibility for final performance? How easy is it to keep deadlines?

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(Continued from page 53 P&R)

Robert F. Orth and Don L. Hinmon have been elected senior vice-presidents of Johns-Manville Corp. Orth, general manager of the Pipe Div., served AWWA as director in 1955–58 and is a past-president of WSWMA. Hinmon will be vice-president for industrial divisions.

Play's the thing along the Potomac these days, as recreationists supporting a Chesapeake and Ohio Canal historical park along the river have expressed their views concerning Washington water supply rights in the following terms:

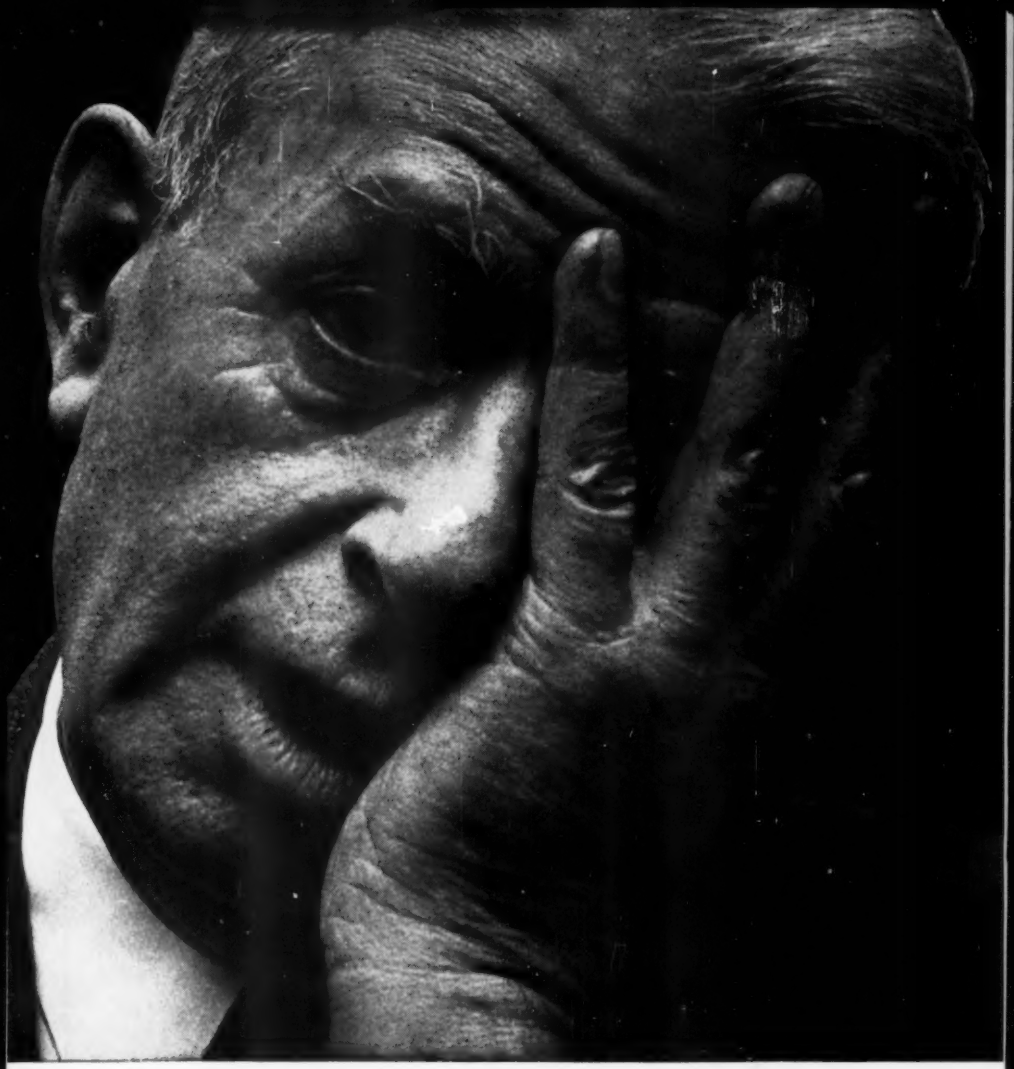
. . . The city no longer has any right to reach out into the countryside with a view to water storage for city supply purposes; these needs should be satisfied from the estuary, the underground pools, the Chesapeake, and the ocean.

In view of the view, the Corps of Engineers is considering studies to determine the feasibility of meeting future Washington water supply needs by drawing supplemental water from the estuary at times of critical low flows in the upper river; driving wells to tap the ground water supplies; and desalinization of salt or brackish water.

We'll be looking for the last act!

First things come first with Lawrence Turpin, an inventor from West Orange, N.J. Recognizing that psychiatrists are even more expensive than plumbers, Turpin attacked the dripping faucet problem from the mental rather than the metal side. Thus, his patented device to overcome the nuisance has not a thing to do with washers or valves; it gets right down to the im-

(Continued on page 56 P&R)



"Did I get burned by a low pump bid!"

"Sure we got a low price on our pumps — 3% lower — but we're plenty sorry we didn't write an experience clause into the specs. We've had nothing but trouble and complaints since those pumps went into operation. Sure the manufacturer is cooperative. Why shouldn't he be. He's using *us* as a guinea pig on an untested design. I can't afford to be a testing department for every 'Johnny-come-lately.' I want pumps that *work*. Next time we'll have an 'experience clause.' When it comes to buying pumps . . . one burn is too many."

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(*Continued from page 54 P&R*)

portant job of eliminating the distracting, nerve-wracking noise of the drip. The Turpin tantrum tamer is, actually, no more than a simple cone-shaped piece of rubber, tipped by a small metal grommet that serves as a capillary valve, letting the escaping water slide silently down a length of string to the drain below. That this kind of gadget aids conversation more than conservation does not seem to bother him at all; he is apparently concerned instead with the thought that he may have discovered the antidote to the Chinese water torture, the piece de resistance to brainwashing, the answer to Communism. At any rate, he and his wife now sleep well at 85 Watchung Ave. despite their landlord's reluctance to rewasher.

George W. Kelsey, vice-president of B-I-F Industries, Inc., Providence, R.I., was installed as president of the WSWMA at the meeting of its board of governors in New York City on Dec. 8, 1959. He was vice-president last year.

Incavation, rather than excavation, seems to be what our Soviet friends are now proposing as an improved technique for laying pipe and cable. The procedure is being developed by the use of a rocket-type tunneling device, the working end of which is fitted with spray nozzles for liquid fuel and compressed air. When ignited, the rocket is said to burn through any type of ground formation. Mains away, we say, and none of your backfill!

(*Continued on page 58 P&R*)

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CHEMICAL QUALITY of the filter sand is also important. It must be hard, not smooth and free of soluble particles. This requires perfect washing, and grading facilities. We have every modern device for washing, drying, screening and testing.

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The new Northeast Station in the City of Detroit, recently completed, is one of the major projects included in the water department's expansion program. The Northern Gravel Company furnished 120 carloads of filtering materials for the 48 rapid sand filters incorporated in this plant.

Northern Gravel has no equal in facilities and our reserves of both sand and gravel are inexhaustible. Northern Gravel Company has been in business over 40 years. We guarantee uniformity of products and our records enable us to duplicate your requirements on short notice. Our location is central and we have commodity rates in every direction.

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(Continued from page 56 P&R)

The 'Joyous NoWell' caption on the Indianapolis Water Co. window display pictured above evoked not only the customary (customery) small smiles and great groans that always greet a pun, but newspaper coverage as well. Thus, in "The Things I Hear" column of the Indianapolis *Star*, John Kleinhenz, director of public relations, who perpetrated the pun, was congratulated on his cleverness, but questioned on the legitimacy of his spelling. For columnist LoWell Nussbaum, the question cleared up any hint of drought, as the letters supporting John's accurate archaicism poured in to provide material for two follow-up stories.

We were inclined to ask, "why not 'Joyo'Us,' " but oWell!

A heartwarming story of water came out of Hahnemann Hospital last November, when a man picked out of a Philadelphia gutter and suffering from long exposure to the frosty night air was brought back to life by the application of warm tap water directly into his chest to thaw out the blood in his heart. It was after a relay of five doctors had massaged the patient's heart for 3 hr, applying heart stimulants of all kinds, that the application of heat directly to the heart was attempted. And when the 6 qt of warm, sterile saline solution available was exhausted, a total of 20 gal of warm tap water was used. By then, the heart had started beating normally and the patient, who had had no anesthesia, tried to climb off the table. His chest was sewed up, he was put to bed, and in a little more than a week was ready to go home—to get into hot, if not warm, water again.

Lost and found could be the answer to two water stories that appeared in the nation's press at the end of December. Up in Alaska, the city of Kodiak reported the loss on Christmas eve of its entire water supply, 61 mil gal in its reservoir having disappeared overnight. Meanwhile, at Touggourt

(Continued on page 88 P&R)

BIG FIVE IN PUBLIC WORKS
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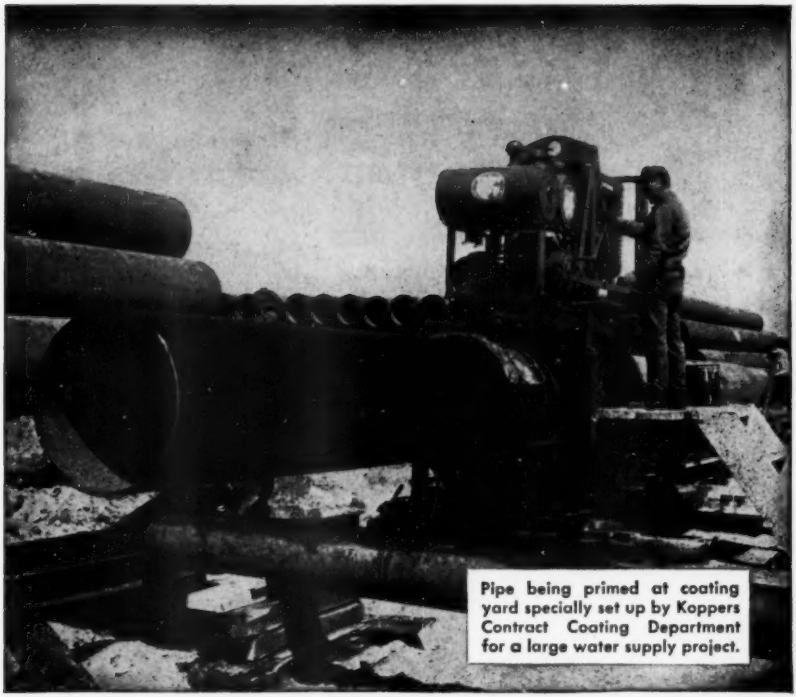

Pipe being primed at coating yard specially set up by Koppers Contract Coating Department for a large water supply project.

3/32" MAKES ALL THE DIFFERENCE

Steel water pipe will last much longer underground with the armor-like protection which a 3/32" coating of Bitumastic 70-B AWWA Enamel gives it. This corrosion-preventive coating is vital to the long-life of water lines.

Bitumastic Enamel has helped steel water lines set high flow capacity records of 40 years and more. Proven performance is one reason why so many water supply engineers are specifying steel pipe, lined and coated with Bitumastic 70-B AWWA Enamel, for their projects today. A lining of this enamel gives a uniformly smooth inside surface that has proved to have the highest flow coefficient available.

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Bal Harbour Technical Program

MONDAY MORNING, May 16

General Session

President's Address ..... Lauren W. Grayson
Challenges of the Water Industry ..... Raymond J. Faust
Aims and Objectives—Committee Report ..... Fred A. Eidsness
Highway-Utility Problems and Programs ..... Sam Houston

MONDAY AFTERNOON, May 16

Management Division—Research

Research in the United States ..... Harry A. Faber
Research in Canada
Research in the United Kingdom ..... R. G. Allen
What AWWA Should Be Doing in Research—Open Discussion .. *Led by* Thurston E. Larson

Water Resources Division—Ground Water

Quality and Waste Disposal ..... Matthew Irvin Rorabaugh
Recharge—Panel Discussion
Richard T. Sniegocki, W. L. Broadhurst, W. Fred Welsch, Robert J. Kleberg Jr., Richard M. Kleberg Jr. & Fred H. Dotterweich
Salt Water Encroachment ..... Francis A. Kohout

TUESDAY MORNING, May 17

Water Works Administration Committee—Open Session

Purification Division—Water Standards

Introduction ..... Ray L. Derby
New US Public Health Service Drinking Water Standards .. O. C. Hopkins & Oscar Gullans
Water Quality Standard ..... Elwood L. Bean
Operator's Viewpoint ..... John R. Baylis
Legal Viewpoint ..... Frank E. Maloney

TUESDAY AFTERNOON, May 17

Management Division—Commercial

Machine Billing Procedures—Panel Discussion
Led by R. D. Tompkins & John G. Copley
Administrative Manuals ..... William D. Hurst
Present Philosophies of Rate Making ..... Samuel S. Baxter

Distribution Division—Water Mains

Water Main Breaks—Panel Discussion
Led by Gerald E. Arnold, Edward J. Clark, Gerald Remus & Howard W. Niemeyer

(*Continued on page 62 P&R*)

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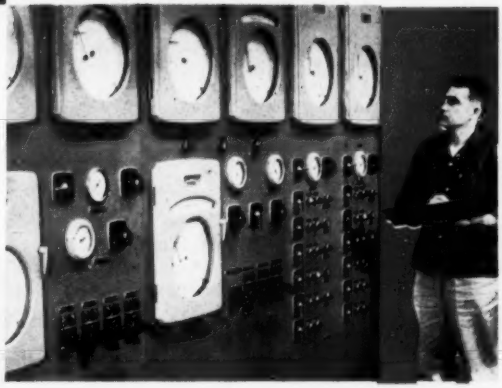

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(Continued from page 60 P&R)

Extension Policies.....Henry J. Graeser
Loss of Pipeline Carrying Capacity.....Thurston E. Larson

Water Resources Division—Water Storage

Joint Sealing in Concrete-Paved Reservoirs.....H. Ward Tyler
Underground Waste Disposal—Task Group Report.....Lynn M. Miller
Ground Water Recharge—Task Group Report.....John J. Baffa
Operating Experiences Under New Water Laws.....Harry E. Jordan
Air-Inflated Dams.....N. M. Ibertson

WEDNESDAY MORNING, May 18

General Session

US Water Resources.....*Senator* Thomas H. Kuchel
Protection of Water Resources.....Mark D. Hollis
Water Resources in Florida.....*Governor* LeRoy Collins
New Constitution and Bylaws.....Lauren W. Grayson

WEDNESDAY AFTERNOON, May 18

Water Works Practice Committee—Open Session

Revision of Positive-Displacement Meter Standard.....James G. Carns Jr.
Various Types of Concrete Pressure Pipe in Use.....Ernest W. Whitlock
Progress in Certification.....Lewis S. Finch
Steel Tank Painting—Including Resins.....J. O. Jackson
High-Tensile Steel.....Louis R. Howson

Purification Division—Coagulation and Reports

Coagulation.....A. P. Black
Discussion.....Rolf Eliassen
Recovery and Reuse of Alum Sludge.....J. M. Roberts
Comparison of Various State Water Works Criteria.....William W. Aultman

THURSDAY MORNING, May 19

Water Resources Division—Surface Supplies

A New Look at Streamflow Data.....Joseph VanBrunt Wells
The Everglades—Past, Present, and Future.....Paul Troxler
Taste and Odor Problems in New Reservoirs Located in Wooded Areas....E. Jerry Allen
Progress in Water Desalting.....Allen Lywin & Lewis S. Finch
Water for Tomorrow.....Gordon E. McCallum

Distribution Division—Pipe, Coatings and Construction

Report on Copper Water Service Study.....Kenneth E. Shull
Plastics and Plastic Pipe.....R. J. Sweitzer
Some Solutions to Unusual Pipeline Construction Problems
H. Arthur Price & Harold L. Gunther
Epoxy Resin Water Works Facilities and Equipment.....Loring E. Tabor

Water Utility Management Division Advancement Session—Financing Water Utilities

The Advancement Program Accomplishments.....Fred Merryfield

(Continued on page 64 P&R)

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(*Continued from page 62 P&R*)

How Bond Issues Were Passed
Fergus Falls, Minn. ..... Howard Sowden
Denver, Colo. ..... Robert S. Millar
Community Relations Is a Day-to-Day Job ..... Thomas F. O'Leary

THURSDAY AFTERNOON, May 19

Water Distribution and Water Utility Management Divisions—Joint Session

Water Demands—Progress Report ..... H. E. Hudson Jr.
Submersible Water Well Pumps ..... Claud R. Erickson
Work Measurements and Standards ..... C. Adleman
Duties and Responsibilities of the Utility Manager ..... William R. Seeger

Purification Division—Pollutants in Water

Estimating Human Radiation Exposure Along the Animas River
E. C. Tsivoglou, S. D. Shearer & J. D. Jones
Pollutants in Water—Panel Discussion
Effects of Fertilizers, Agriculture, and Aquatic Chemicals ..... Clarence M. Tarzwell
Effects of Salinity Caused by Irrigation ..... L. V. Wilcox
Effects of Sewage and Industrial Wastes ..... Ralph E. Fuhrman
Effects of Syndets ..... Graham Walton
Effects on Taste and Odors ..... H. O. Hartung

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MONDAY, May 16

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Awards Evening ..... Americana

TUESDAY, May 17

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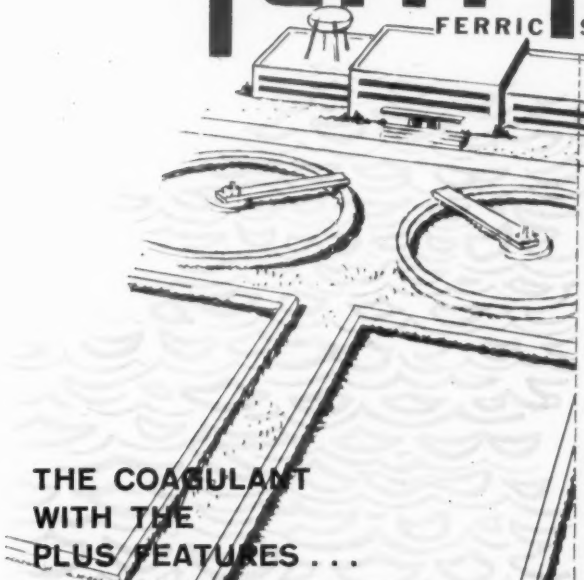

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Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

POLLUTION CONTROL

Pollution Control of Water Supply Reservoirs. J. E. TRYGG. *Southwest Water Works J.*, 40:4:16 ('58). In a paper presented at Southwest Section of AWWA at Oklahoma City, Okla., in Oct. '57, author discussed difficulties encountered in practical control of poln. of impounding reservoirs. A list of factors to be considered in determining whether a reservoir should be used for unlimited aquatic sports is given and policy of Louisiana State Dept. of Health with regard to problem is outlined.—*WPA*

Measures for Protection of Surface Waters Against Pollution—An Eleven-Country Report. *Gas- u. Wasserfach.*, 98:1207 ('57). A summary is given of measures for protection of surface waters in Austria, Belgium, Denmark, W. Germany, France, Gr. Britain, Italy, Netherlands, Spain, Switzerland, and US. Summary is divided into sections dealing with existing legislation and its main provisions, financial provisions for industrial treatment plants, general standards for composition of surface waters and of waste waters discharged, and regional water authorities and their powers and duties.—*WPA*

How to Cut Down Pollution of Streams and Ditches. W. F. LESTER. *Munic. Eng.*, 135:14 ('58). Author suggests several ways in which stream poln. can be reduced considerably. He discusses improvements in farm practices over past 20 yr and stresses importance of careful discharge of waste waters from dairies, piggeries, silage production, and pea canneries. There is some risk that poisonous materials used in pest or weed control may reach a stream directly or may be subsequently washed into stream by rain; hence, skillful operation is necessary. Care must also be exercised when using water weed killers or sheep dip.—*WPA*

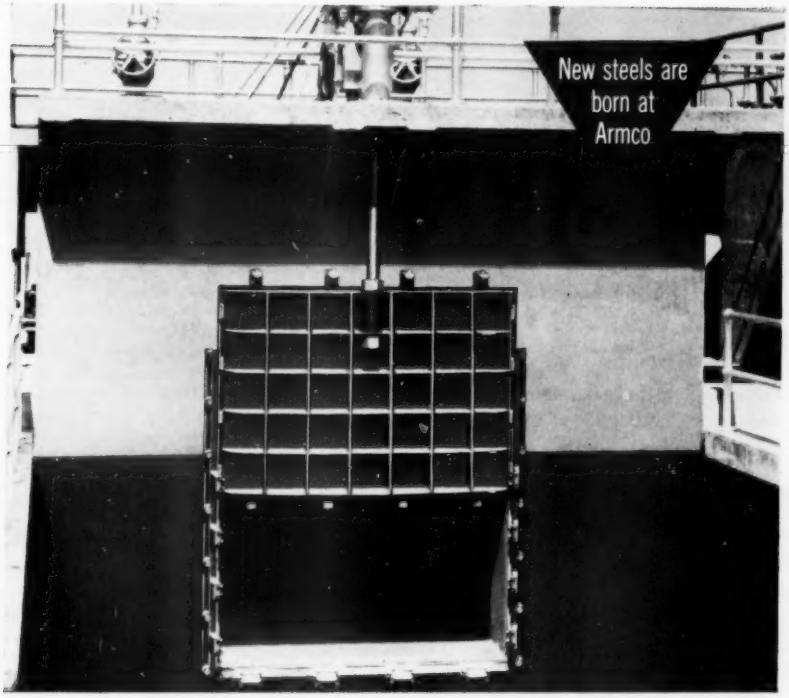
Recent Legislation Affecting Industrial Waste Disposal. N. NEMEROW & W. L. WILSON. *Ind. Eng. Chem.*, 50:295A ('58). Federal Water Pollution Control Act of 1956 is summarized and state of legislation concerning water poln. control in individual states is discussed, including tentative proposals of a Model Water Use Act which Univ. of Michigan Law School has been asked to prepare on behalf of National Conference of Commissioners on Uniform State Laws.—*WPA*

Laws and Regulations Concerning the Protection of Water From Pollution. N. D. BAENST. *Bul. Mens. Centre Belge Et. Documentation Eaux* (Liege), 64:151 ('56). Author discusses laws governing control of pollution of surface waters in Belgium; regulations controlling treatment of sewage and trade waste waters before discharge to surface waters; and conditions under which sewage and trade waste waters may be discharged, based on classification of surface waters. A table, showing classification of surface waters and discharge allowed, is included.—*WPA*

Pollution Control in New England. W. S. WISE. *Sew. & Ind. Wastes*, 30:86 ('58). Author discusses problem of controlling water poln. in New England states, and describes constitution and work of the New England Interstate Water Pollution Control Commission.—*WPA*

Pollution of Waters by Industrial Wastes. A. V. DELAPORTE. *Canad. J. Public Health*, 49:154 ('58). Since 1913, Ontario has changed from an agrarian to an industrial economy and consequently problem of industrial waste waters has become an important one. In an effort to control discharge of toxic industrial waste waters to surface waters, Ontario Water Resources Commission

(Continued on page 76 P&R)



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(*Continued from page 74 P&R*)

adopted objectives for control of water quality; these objectives are more restrictive than those of International Joint Commission for boundary waters. To obtain more complete information on the organic compounds causing poln., activated-carbon filters are being used and constituents obtained identified spectrographically.—*WPA*

Biochemical Degradation Products—A New Dimension in Stream Pollution. R. H. BOGAN. *Sew. & Ind. Wastes*, 30:208 ('58). Experience with persistent organic substances has led to conclusion that organic stream pollutants cannot be evald. adequately in terms of BOD or chemical oxygen demand alone. Neither test describes qual. nature of residual organic substances which may be present after varying periods of biochemical oxidation. Expts. have shown presence of biochemical degradation intermediates or byproducts during breakdown of oils and alkyl benzene sulfonates, and there is a possibility that such intermediates may be produced from a no. of other sources. Oxidation of an organic compd. may be related to a portion only of original molecule. Through hydrolysis and fission, a substance may be broken into 2 or more fragments, and it is possible that some fragments may be relatively resistant to oxidation while others may be oxidized rapidly. Many consecutive enzyme reactions may be involved in degradation of an organic compd., and some of these reactions have been found to take place at widely different rates. Evidence indicates that certain enzyme reactions such as fissioning of benzene ring may regulate rate at which a substance can be oxidized, and biochemical degradation products may accumulate at such reaction points.—*WPA*

The Role of Algae in Pollution Abatement. J. BORCHARDT. *Public Works*, 89:109 (Dec. '58). Algae studies conducted during past 2 yr at Univ. of Michigan are described. An effort is being made to understand part algae play in natural recovery in streams, and rates at which they metabolize waste. If this can be accomplished, algae might be used in sewage treatment plants. Unialgal cultures have been studied. To determine numbers and sizes, an inverted scope has been used. A device has also been constructed which will maintain a constant light intensity for the duration of an expt. Many

(*Continued on page 78 P&R*)

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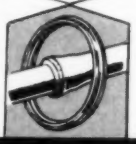

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(Continued from page 76 P&R)

of algae types used in sewage lagoons are very small and present difficult problems of removal, and current laboratory studies are being conducted ranging from centrifuging to cultivation of antagonistic forms. One possible soln. to problem of removal is to develop flocculent masses similar to those formed by *Zooglea ramigera* in activated-sludge process, and which will readily settle.—*PHEA*

Determination of the Dilution Rate of Sewage for Sanitary Control of Water Reservoirs. M. A. RUFFEL. *Hyg. & Sanit.* (Moscow), 23:3:19 ('58). Rate of dilution of sewage discharged into reservoirs cannot be calcd. by methods used when considering effect on natural streams, owing to different conditions governing mixing of water. A method and formulas are presented for calcg. rate of dilution of effluents discharged into a reservoir, either at bank or at a distance from bank (at a given depth). Results obtained by this method agreed satisfactorily with values obtained by direct analysis of the water in 4 reservoirs.—*WPA*

Water Conservation and Pollution Abatement Through the Chemical Treatment and Sludge Dewatering of Mill Scale Wastes. G. A. PETTIT. *Ind. Wastes*, 3:133 (Nov.–Dec. '58). Removal of heavy and fine mill scales, oils, and grease from all roughening and finishing mill wastes at a steel plant is described. Treatment consisted of a collection system, sedimentation basin, pumping station, mixing tank, flocculators, circular clarifiers and a chemical building containing 2 vacuum filters. Clarified effluent was acceptable for reuse on certain processing units within mill.—*PHEA*

Problems and Control of Unnatural Fertilization of Lake Waters. J. H. NEIL. *Proc. 12th Industr. Waste Conf., Purdue Univ. Eng. Extn. Ser.*, No. 94, p. 301 ('57). After discussing briefly factors affecting productivity of lakes under natural conditions, author discusses effects of unnatural enrichment. Factors leading to increased enrichment include clearing of forests and farming of land (which accelerate erosion), use of chemical fertilizers, and increased trend of urbanization. Unpleasant blooms of blue-green algae occurred in Sturgeon lake, one of a series of relatively shallow unstratified lakes in southern Ontario. Investigations

(Continued on page 80 P&R)

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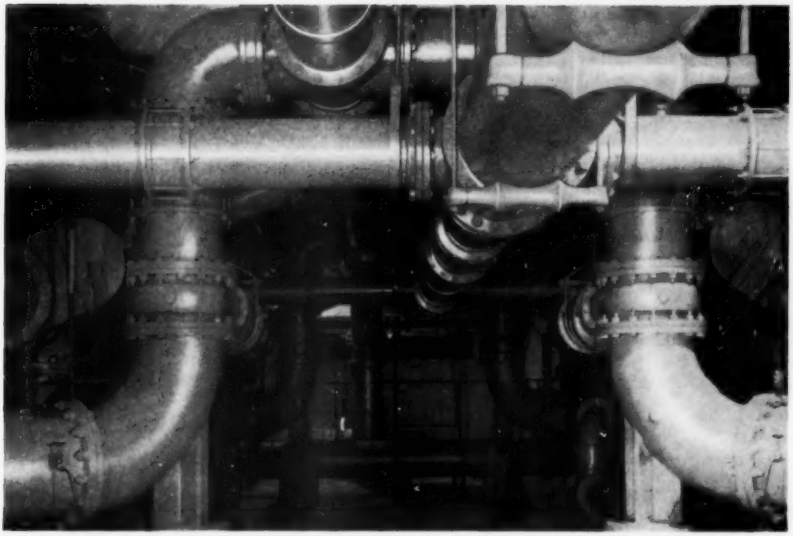

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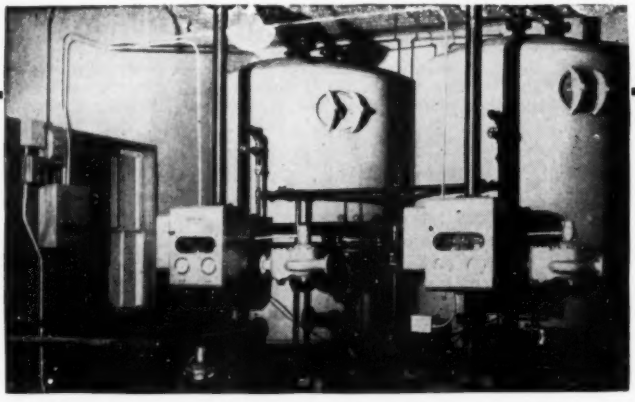
(Continued from page 78 P&R)

were carried out over a period of years on factors affecting productivity and it was found that phosphorus appeared to be an important factor, although other factors, such as climatic conditions and presence of other chemical constituents, also affected rate of algal growth. Greatest single source of phosphorus was found to be primary sewage treatment plant at town of Lindsay, effluent from which is discharged to a river flowing into lake. Expts. showed that phosphate could be removed by chemical coagulation of crude sewage with alum and activated silica, and it is suggested that this method of control could be applied if algal blooms should in future occur consistently in lake. As volume of water flowing through lake is relatively large, although nutrients may accumulate slowly, under present conditions, level of nutrients would be lower if such control were applied. However, this would not be case in lakes with low flow, where accumulated nutrients would tend to be circulated continuously.—*WPA*

Phosphate Compounds Occurring in Illinois Surface Waters. J. DIETZ & R. HARMESON. *Proc. 12th Industr. Waste Conf., Purdue Univ. Eng. Extn. Ser.*, No. 94, p. 285 ('57). As Illinois is situated in a hard-water region where use of synthetic detergents could be expected to increase, a study was made of concns. of phosphate occurring in surface waters and effects of these concns. on coagulation of water with alum. After a prelim. survey of streams in state, Kaskaskia R. was selected for a more detailed study. Lab. expts. on effect of phosphates on coagulation were made with a synthetic turbid water, to eliminate as many variable factors as possible. Except in unusual circumstances, only low concns. of phosphate were found in most lakes, reservoirs, and streams. Higher concns. occurred in rivers receiving heavier sewage loads. In survey of Kaskaskia R. it was found that concn. of phosphate became progressively higher downstream, as volume of sewage discharged to river increased; there

(Continued on page 82 P&R)



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American cities have been steadily increasing in population and likewise spreading out into suburbs and "suburbs of suburbs". So more water is needed and distribution mains need to be longer with more valves and fire hydrants and more footage of main per customer. Engineering experts agree that to give adequate service, U. S. water and sewage facilities today need to be doubled!

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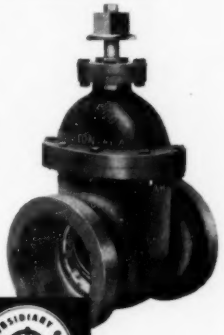

This series is an attempt to put into words some appreciation of the water works men of the United States.

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(Continued from page 80 P&R)

may also be more phosphate contributed by drainage from land surfaces as area drained increases. Laboratory expts. showed that tetrasodium pyrophosphate and sodium tripolyphosphate had a greater effect on coagulation and sedimentation than did either monosodium or disodium orthophosphate. In none of the experiments was it necessary to use more than 12 ppm alum to obtain residual turbidities of less than 5 ppm, and concn. of phosphate used in these expts. was higher than concns. found in streams. It is recommended that further studies should be made to determine amts. of phosphate contributed from different sources such as sewage treatment plants and agricultural drainage.—*WPA*

Movement of Coliform Bacteria Through Porous Media. R. KRONE; G. ORLOB; & C. HODGKINSON. *Sew. & Ind. Wastes*, 30:1 ('58). In recharge of ground water with sewage, a no. of problems arise concerning movement and survival of bacteria. Expts. have now been carried out on fundamental behavior of coliform bacteria during their movement into and through porous media. As a result of greater sensitivity of bact. techniques, presence of bacteria in percolating water is often detected earlier than the presence of chemical tracers. First contamd. water to arrive at a given point includes bacteria that have travelled with fastest moving water farthest from periphery of stream where removal potential is greatest. Ultimately almost all the bacteria are removed by medium or their movement is retarded sufficiently for natural bactericidal forces to act. 2 removal mechanisms have been observed, straining in contact zones of adjacent grains and sedimentation in pores. At first both removal mechanisms are operative, and straining mechanism increases its rate of removal as individual bacteria accumulate in contact zones. When accumulations become unstable, portions break off as clusters which are removed subsequently by straining or sedimentation. When first clusters break off at surface, large nos. of bacteria rapidly saturate straining sites for some distance be-

(Continued on page 86 P&R)

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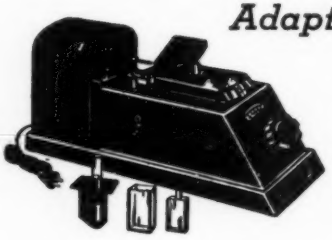

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(Continued from page 82 P&R)

low, after which saturated front moves downward more slowly. Sedimentation removal mechanism has a relatively great saturation capacity. Rate of removal of bacteria by sedimentation mechanism is related to rate of flow, size, and density of bacterial cluster. This mechanism also becomes saturated first at soil surface, and controls subsequent passage of bacteria. It therefore appears that soil surface plays a dominant role in subsequent travel of bacteria, and operates in such a manner as to restrict continued infiltration of bacteria. Interpretation of exptl. data depends on an estimation of densities of individual bacteria or bacterial clusters. More reliable data are needed on both the physical characteristics of bacteria and clustering phenomenon as related to liquid velocity.—*WPA*

Ground Disposal of Radioactive Wastes. C. B. AMPHLETT. *Atomics & Nuclear Energy*, 9:194 (Jan. '58); 9:242 (Jul. '58). Factors to be considered in deciding on a method for ground disposal of radioactive wastes are reviewed. Factors in site selection include ground water movement, height of water table, rainfall, permeability and porosity of soil, exchange capacity of soil, chem. reactions between waste and ground water and soil. Fortuitous combination of geogr., geol., and hydrol. factors at Hanford and extent to which this area is utilized for disposition or "storage" of low-level wastes are described. Oak Ridge and Savannah River Project experience with surface pits is referred to. Canadian practices in ground disposal following NRX reactor accident and planned disposal is indiciated. Prospects of deep well disposal into connate waters of high-level wastes are discussed, including the need for cooling fresh wastes before injection. In conclusion, author states that, although ground disposal is a well tried method under suitable conditions for low-activity wastes, it is problematical whether it can also be applied to highly active ones.—*PHEA*

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(Continued from page 58 P&R)

on the Sahara Desert, French engineers reported striking a vast underground deposit. Kodiak city fathers suspected that their water drained down a fissure created by recent earthquakes. The French apparently are above suspicion in estimating their find at 2.75 bil gal. Kodiak's 1,710 persons are getting along on emergency boiled rations, while the city's canneries and other industries are shut down. In the Sahara, the "vast" supply is at yet untapped. Fissure stories are like that!

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Frank C. Amsbary Jr., vice-president and general manager, Long Island Water Corp., Lynbrook, L.I., and former president of the Association, died Jan. 31, 1960, at the age of 59. Born in 1900, he received his degree in civil engineering at the University of Illinois in 1922. He served with the Champaign-Urbana Water Co. (now the Northern Illinois Water Co.) from 1923 to 1955, and was vice-president when he left to join the Long Island Water Corp.

A member of AWWA since 1927, he received the Fuller Award in 1941 on nomination of the Illinois Section. He served the section as chairman in

(Continued on page 90 P&R)

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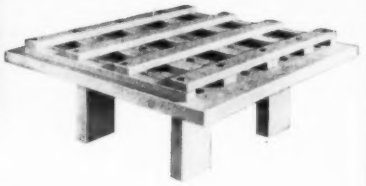

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(Continued from page 88 P&R)

1937 and as director in 1939–42. He was AWWA vice-president in 1955 and president in 1956. A Life Member of the Association since 1957, he was elected to Honorary Membership by the Board in January 1959.

Other organizations to which he belonged include ASCE and the National Society of Professional Engineers.

W. Wayne Glover, director of research and development, Simplex Valve & Meter Co., died December 11, 1959. Starting with Simplex in 1924, he attended night school at Drexel Institute, from which he received his diploma in mechanical engineering. He became chief engineer in 1943 and assumed his present position in 1958. He was a member of AWWA since 1942.

Arthur Pew Jr., president, Arthur Pew Construction Co., Chamblee, Ga., died Nov. 30, 1959, in Paris, France, at the age of 61, during a European vacation. Born near Auburn, Ala., he attended the University of Georgia. He was an AWWA member since 1953.

Morrell Vrooman, senior partner and founder of Morrell Vrooman Engineers, Gloversville, N.Y., died Nov. 7, 1959, at the age of 84. After attending Cornell University, he became city engineer of Gloversville in 1901 and founded his engineering firm in 1913. During World War II he served as chief engineer in charge of construction at Fort Dix, N.J.

A member of AWWA since 1913, he became a Life Member in 1943. He was also a life member of ASCE and a charter member of the New York State Sewage & Industrial Wastes Assn.

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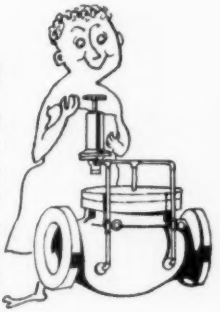

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Cast Iron Pipe Research Assn.
Steel Plate Fabricators Assn.

Brass Goods:
American Brass Co.
Hays Mfg. Co.
Mueller Co.

Brine-Making Equipment:
International Salt Co., Inc.

Calcium Hypochlorite:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.

Carbon Dioxide Generators:
Walker Process Equipment, Inc.

Cathodic Protection:
Electro Rust-Proofing Corp.

Cement Mortar Lining:
Centriline Corp.
Halliburton Oil Well Cementing Co.
Southern Pipe Div. of U.S. Industries

Chemical Feed Apparatus:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Graver Water Conditioning Co.
F. B. Leopold Co.
Permutit Co.
Precision Chemical Pump Corp.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Chemists and Engineers:
(See Professional Services)

Chlorination Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Chlorine Comparators:
Fischer & Porter Co.
Klett Mfg. Co.
Wallace & Tiernan Inc.

Chlorine, Liquid:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.
Wallace & Tiernan Inc.

Clamps and Sleeves, Pipe:
James B. Clow & Sons
Dresser Mfg. Div.
Ludlow Valve Mfg. Co., Inc.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.

Clamps, Bell Joint:
James B. Clow & Sons
Dresser Mfg. Div.

Clamps, Pipe Repair:
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.

Clarifiers:
American Well Works
Chain Belt Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

for Public Water Fluoridation

Sodium Silicofluoride – 99%

(Powder)

Sodium Fluoride – 98%

(Powder or Granular)

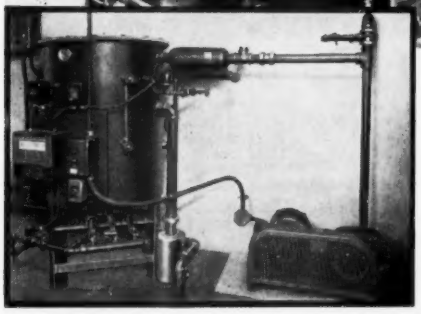
Meet AWWA specifications

White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
Minimum of dust in handling

THE AMERICAN AGRICULTURAL CHEMICAL COMPANY

100 Church Street, New York 7, N. Y.

AA QUALITY



Four size 4 Carballs at Kansas City, Mo. burn either gas or oil to produce max. of 40,000 lbs. CO_2/day. Size "O" unit at left produces 570 lbs. CO_2/day for Jefferson, Iowa Water Plant.

CARBALL
CO_2 UNIT

Walker Process now offers carbonation units for all lime softening plants from the very small to the largest. Sizes range from the new "OO" unit with minimum capacity of 55 lbs. CO_2/day to the No. 4 at maximum output of 10,000 lbs. CO_2/day.

Engineers can readily provide an entire carbonation system by simply specifying the appropriate size CARBALL in combination with Walker Process SPARJER diffusers . . . . . assuring

50% More CO_2
Clean, Tasteless Gas
100% Combustion
Unique Absorption Method
Economical Operation
Factory Tested Package System

Write for bulletins 7W83 - 7W85 and 7W88

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA ILLINOIS

Coagulant Aids:
Hagan Chemicals & Controls, Inc.
Nalco Chemical Co.
Philadelphia Quartz Co.

Condensers:
Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.
Worthington Corp.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Simplex Valve & Meter Co.

Copper Sheets:
American Brass Co.

Copper Sulfate:
General Chemical Div., Allied Chemical Corp.
Tennessee Corp.

Corrosion Control:
Calgon Co.
Nalco Chemical Co.
Philadelphia Quartz Co.
Southern Pipe Div. of U.S. Industries

Couplings, Flexible:
DeLaval Steam Turbine Co.
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
E. H. Wachs Co.

Covers, Vault:
Ford Meter Box Co.
E. H. Wachs Co.

Desalinization Plants:
Emhart Mfg. Co., Maxim Div.

Diaphragms, Pump:
Dorr-Oliver Inc.

Engineers and Chemists:
(See Professional Services)

Evaporating Equipment:
Emhart Mfg. Co., Maxim Div.

Feedwater Treatment:
B-I-F Industries, Inc.—Proportioneers
Calgon Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Nalco Chemical Co.
Permutit Co.

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
Dicalite Div.
General Filter Co.
Johns-Manville Corp.
Multi-Metal Wire Cloth Co., Inc.
Northern Gravel Co.
Permutit Co.
Stuart Corp.

Filters, Incl. Feedwater:
B-I-F Industries, Inc.—Proportioneers
Dorr-Oliver Inc.
Graver Water Conditioning Co.
Permutit Co.
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filtration Plant Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
Chain Belt Co.
Filtration Equipment Corp.
General Filter Co.
Golden-Anderson Valve Specialty Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Multi-Metal Wire Cloth Co., Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.
Olin Mathieson Chemical Corp.
Tennessee Corp.

Fluoride Feeders:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Foxboro Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Worthington Corp.

Glass Standards—Colorimetric Analysis Equipment:
Fischer & Porter Co.
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Mueller Co.
Southern Pipe Div. of U.S. Industries

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Photovolt Corp.
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Intake Screens:
Multi-Metal Wire Cloth Co., Inc.

Ion Exchange Materials:
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Nalco Chemical Co.
Permutit Co.
Roberts Filter Mfg. Co.
Rohm & Haas Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

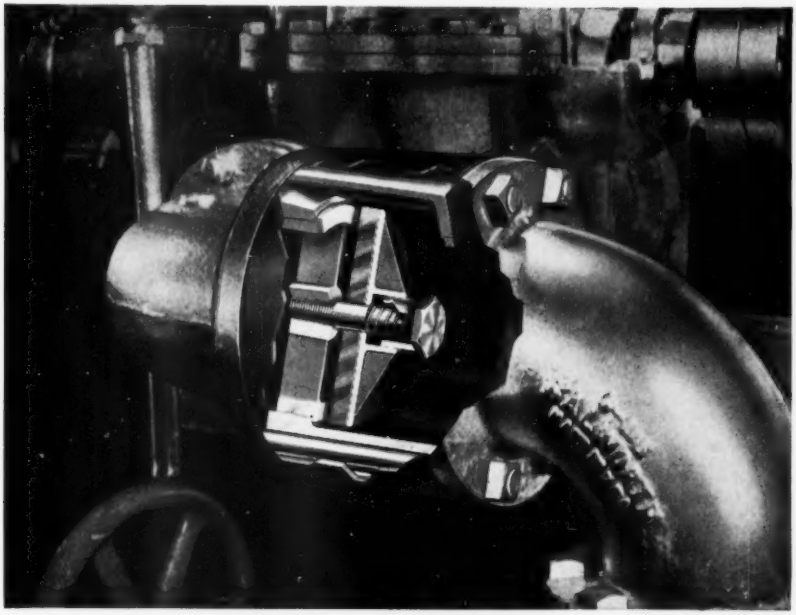
Lime Slakers and Feeders:
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

Locators, Pipe & Valve Box:
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Magnetic Dipping Needles:
Aqua Survey & Instrument Co.
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Rockwell Mfg. Co.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.



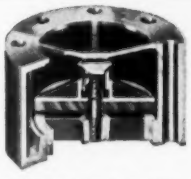
ELIMINATE BACK-DROP, SURGE AND HAMMER

When CPV silent, non-slam check valves are installed on the discharge of centrifugal pumps, the whole system is protected against waste and harmful surges. The need for expensive air cushions and other anti-hammer devices is eliminated.

Spring-actuated, CPV check valves close automatically as soon as flow ceases. Back travel, which can be so damaging, is not required for closing.

Users report CPV valves easy to install and require no maintenance. Unique design includes bearing guides on both sides of disc and a full flow area in excess of pipe area. The valve operates in any position.

For complete specifications and prices write Combination Pump Valve Company, 853 Preston Street, Philadelphia 4, Pa.



STYLE "G"—2 to 10"

STYLE "GB"—6" and up

CPV SILENT NON-SLAM CHECK VALVES

Hays Mfg. Co.
Hersey-Sparling Meter Co.
Mueller Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Fischer & Porter Co.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
F. B. Leopold Co.

Motors, Electric:
Allis-Chalmers Mfg. Co.
Ideal Electric Co.
Worthington Corp.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
James B. Clow & Sons
Southern Pipe Div. of U.S. Industries
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
American Hard Rubber Co.
Morgan Steel Products, Inc.
Orangeburg Mfg. Co., Div. of The Flintkote Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries

Pipe Cleaning Services:
Centriline Corp.
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
American Hard Rubber Co.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Shell Chemical Corp.
Southern Pipe Div. of U.S. Industries

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
E. H. Wachs Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Fischer & Porter Co.
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
Nalco Chemical Co.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
Nalco Chemical Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

AT ELEVEN PLANTS ACROSS THE COUNTRY, Jones receives tank cars of Chlorine, repackages it in cylinders and 1-ton tanks, makes quick deliveries to users in area.

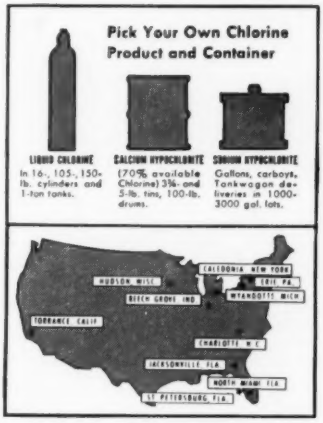
ONE convenient source for all your chlorine needs

Get chlorine products any way you want them, in any amount you need, from just *one* dependable source—Jones Chemicals.

It eliminates hop-scotch buying of liquid chlorine, calcium hypochlorite, or sodium hypochlorite, and enables you to plan your needs and deliveries . . . avoid excess storage. Eleven Jones plants, strategically located across the U.S., stand ready to deliver chlorine products *when you need them.*

Get chlorine in any amount—from 16-lb. cylinders to 1-ton tanks. Jones packages high-purity chlorine in less than carload lots. You pick the size and type of container you need.

Our trained technical staff will be glad to help you with your chlorine problems. Write for information and prices, or contact the Jones plant nearest you.



John Wiley

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"A good name in chemicals"

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Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permutit Co.

Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Inc.

Tank Painting and Repair:
Koppers Co., Inc.
National Tank Maintenance Corp.
Taylor Iron Works

Tanks, Prestressed Concrete:
Preload Co., Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.
Taylor Iron Works

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Permutit Co.
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey-Sparling Meter Co.

Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
A. P. Smith Mfg. Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.

Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
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